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FEASIBILITY OF ESTABLISHMENT OF VEGETATION FOR CAMOUFLAGE THROUGH HYDROPLANTING TECHNIQUES

by

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Final Report

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Hydroplanting tests were conducted with a 500-gallon hydromulcher equipped with a mechanical agitator and gear pump in applications of water-slurry mixtures of wood fiber mulch, seed or other propagation material, fertilizer and soil stabilizers or other additives. Preliminary laboratory and greenhouse tests on some 88 species of grasses, broadleaf plants and vines provided a basis for selection of plants for the field test program.

A series of 9 field tests established that cool-season and warm-season plants could be established readily by the hydroplanting technique in the Frederick area. Vegetation coverage was accomplished in 15 to 30 days on bare soil areas provided that the soils were not severely compacted and that moisture was available during the germination and emergency periods. The most promising grasses were foxtail millet, Proso millet, sorghum-sudan hybrid, weeping lovegrass, oats and bermudagrass. Rapidly-established broadleaf plants included buckwheat, rape and hairy vetch. Three species of gourd vines were established by hydroplanting techniques but failed to give satisfactory growth under the conditions of high temperature and limited moisture.

General guidelines were established as to the quantities of wood fiber mulch (1500 to 3000 lb/acre), fertilizer, and other slurry components for effective establishment. Seeding rates utilized were obtained from agronomic literature.

The feasibility study showed that vegetation covers, consisting principally of grasses, could be established rapidly by hydroplanting and provide stands comparable in density to those established by other cultural methods. Limited aerial photographic imagery with Ektachrome and Infrared Ektachrome film indicated that the hydroplanted vegetation covers compared favorably with established vegetation in camouflage characteristics.

ABSTRACT

A greenhouse and field test program was conducted by the Vegetation Control Division at Fort Detrick, March - September 1973, to evaluate the feasibility of establishment of vegetation cover as camouflage on disturbed soil areas by hydroplanting techniques. A need exists for a camouflage technique which will provide rapid establishment of vegetation cover on spoiled surfaces in missile sites, base camp perimeters and other military installations.

Hydroplanting tests were conducted with a 500-gallon hydromulcher equipped with a mechanical agitator and gear pump in applications of water-slurry mixtures of wood fiber mulch, seed or other propagation material, fertilizer and soil stabilizers or other additives. Preliminary laboratory and greenhouse tests on some 88 species of grasses, broadleaf plants and vines provided a basis for selection of plants for the field test program.

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FOREWORD

The study described in this report was conducted under U. S. Army Land Warfare Laboratory Task 31B-73 by the Vegetation Control Division, Fort Detrick in response to a request from the Mobility Equipment Research and Development Engineering Center at Fort Belvoir, Virginia, through the LWL at Aberdeen Proving Ground, Maryland.

Mr. Nick Montanarelli provided overall coordination of the project. Mr. J. Ray Frank and Dr. William C. LeCroy directed all phases of the laboratory, field and greenhouse studies. Mr. Paul C. Goetz, Mr. Dennis Katchur and Mr. Kenneth D. Demaree assisted in various phases of the greenhouse and field program. CPT Billy Morrison and Dr. Robert A. Darrow coordinated the aerial photographic missions. The missions were flown by members of the USAF Reserve under the direction of MAJ Price from Shaw Air Force Base. Mr. James S. Slechta of the U. S. Army Imagery Interpretation Center at Fort Holabird served as interpretor of film exposed on aerial flights.

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INTRODUCTION

The mobility of current military operations often leads to the establishment of temporary bases with extensive areas of bare soil compacted by heavy equipment and topsoil removed either mechanically or by wind and water erosion. Natural revegetation on such sites may be extremely slow and there is a critical need for rapid establishment of vegetation cover to reduce their visibility from the air and to provide stabilization from wind and water erosion.

This report deals with a feasibility study of hydroplanting techniques in the development of vegetation cover on spoiled surfaces or disturbed soil and natural terrain for camouflage purposes.

BACKGROUND INFORMATION

Prior consideration of living vegetation as a feasible camouflage techniques had not been made due to the previous unavailability of suitable equipment for establishment of vegetation adaptable to military situations. The recent development of hydroplanting and hydrograssing equipment for use on highway embankments and rights-of-way has now provided a technique which may be adaptable for military use. These techniques provide a capability for the establishment of grasses and other types of vegetation by application of a slurry containing water, seed or other plant propagules, fertilizers, and a mulch. Mechanized equipment for hydroplanting is currently available on the civilian market.

Evaluation of this general technique was conducted to determine its general application and feasibility in military situations requiring camouflage of spoiled surfaces.

OBJECTIVES

Objectives of the project were determination of the feasibility of hydroplanting techniques for military use and comparison of this system with other recognized planting methods on bare soil or spoiled surfaces. Major areas of concern were the rapid establishment of adapted species and the development of a cover of vegetation with suitable camouflage characteristics.

Specific objectives of the feasibility study as outlined in the original proposal were:

1. To select plant species of rapid growth habit, adaptable to establishment by the hydroplanting technique.

2. To develop appropriate growth-promoting media or substrates with incorporation of locally available materials which might be used in hydroplanting equipment.

3. To determine the useful life of living vegetation cover and the associated substrate established by hydroplanting techniques.

4. To evaluate the capability of the established vegetation cover to withstand wind and water erosion when applied to soil surfaces and natural terrain.

5. To evaluate the camouflage properties of candidate vegetation covers and associated substrates by infrared or camouflage detection imagery or other surveillance techniques.

During the course of the study an initial requirement for study of the development of vegetation cover on buildings, equipment and on camouflage netting or similar materials was withdrawn and the entire emphasis of the program was devoted to the development of vegetation cover on disturbed soil areas.

SUMMARY AND CONCLUSIONS

A greenhouse and field test program conducted from March through September 1973 demonstrated the feasibility of establishing vegetation cover by hydroplanting techniques on disturbed soil areas in the vicinity of Frederick, Maryland.

Laboratory and greenhouse tests of germination and emergence were made on 88 species of grasses, broadleaf plants and vines as a basis for selection of suitable plants for hydroplanting with field equipment. In the initial greenhouse work, evaluations were made of artificial media and substrates for establishment of vegetation on nonsoil areas. These tests on artificial substrates were generally unsatisfactory because of the high moisture requirements for plant growth under greenhouse conditions, and were subsequently terminated in preference to continued research on soils.

Field tests were made with a 500-gallon Bowie Hydromulcher equipped with mechanical agitator, gear pump, and 50-foot delivery hose and nozzle for application of the slurry mixtures to test plots. Tests were made at two areas in a series of 9 experiments using replicated 20 x 30 ft plots. Variables studied included species mixtures, mulch rates, fertilizer rates, soil stabilizers and methods of stand density or percent cover by species components and by periodic photographs. A series of three aerial photographic overflights provided imagery coverage with panchromatic, Ektachrome and Infrared Ektachrome film from an altitude of 1500 ft.

Climatic conditions during most of the field season favored the development of warm season species. Grasses successfully hydroplanted and showing rapid establishment of vegetation cover within 10 to 14 days included: foxtail millet, Proso millet, sorghum-sudan hybrid, weeping lovegrass, oats and bermudagrass. Under these conditions, buckwheat, rape and hairy vetch were the most desirable broadleaf species. None of the vines tested gave satisfactory establishment and growth under the field conditions of high temperatures and limited moisture. Annual ryegrass was one of the most effective cool-season plants tested; other cool season grasses were established successfully in early field tests but showed minimal growth until cooler conditions at the end of the field season.

Wood or pulp fiber mulch was an essential component of the slurry mixture at rates of 1500 to 3000 lb/acre for slopes or areas low in moisture or at 1000 to 1500 lb/acre on level areas with suitable moisture conditions. Limited tests with soil stabilizers including Curasol and Terratack appeared to show some benefit in reducing moisture loss and thus increasing plant growth.

Hydroplanting or hydroseeding techniques appear to give a more rapid and more complete vegetation cover than other planting methods. Hydroplanting tends to help initiate seedling growth and development by the action of physically imbedding the seed, mulch and water-slurry mixture into the previously loosened soil. Incorporation of the wood fiber mulch helps to hold moisture and thus improve germination and emergence conditions.

Species which are hydroplanted successfully are subsequently limited principally by the amount of available mositure, nutrients, temperature, and their life cycle during periods of high temperature. Mixtures of warm-season annuals and cool-season perennials are advantageous in providing a continuous vegetation cover.

Visual, photographic and aerial photographic observations indicate that hydroplanting techniques are satisfactory for the development of vegetation cover on bare soil under favorable conditions.

METHODS AND RESULTS

The general test program was divided into two general phases based on the seasonal conditions for plant growth and the availability of hydromulching equipment. Initial studies were conducted in the greenhouse and laboratory to provide information on species selection and suitable substrates and slurry mixtures for hydroplanting; the latter and principal portions of the studies involved field tests using hydroplanting equipment made available in early June 1973.

Greenhouse and laboratory tests

Germination and Emergence Studies.- Plant species to be used in a hydroplanting program should exhibit rapid germination and establishment from seed, or, if propagated vegetatively, fast development of root systems. With speed of plant establishment as a primary prerequisite, selections of grasses, broadleaf herbaceous plants, and vines were made for use in preliminary germination and emergence studies. Evaluations were made of 88 kinds of plants in the total program. A reference list of the plants tested is given in Appendix A.

Preliminary tests of grasses and broadleaf plants were largely confirmatory germination tests on available seed lots in germination chambers and direct seeding tests in peatmoss pots (Jiffy Sevens) and soil mixtures. Specific germination data were generally available in agronomic literature on the species selected from these two groups.

More comprehensive studies were made on a group of 35 vines for which such information was not available in the literature. Germination and establishment behavior was studied under varied conditions as outlined in Table 1. Data on the rate of height growth and area coverage of a representative group of species are presented in Table 2. These tests indicated that under favorable growing conditions including adequate moisture, rapid establishment could be secured of cypress-vine, balsam-apple, Ovifera gourd and Lagenaria gourd. (Figures 1 and 2).

TABLE 1

GREENHOUSE AND LABORATORY STUDIES OF GERMINATION AND ESTABLISHMENT OF VINES

Test No.	Treatment	No. of Species	Remarks
1	Seed germinated in germinator cabinet; seedlings transferred to peat pots and then to soil	25	No germination of 8 spp. 4 spp. unsuccessful in transplanting
2	Seeded directly in peat pots	23	Successful establishment of large-seeded spp.
3	Seeded directly in peat pots; seedlings transplanted to soil	18	Cypress-vine, balsam-apple, Ovifera gourd, and Lagenaria gourd gave best development; growth data presented in Table 2.
4	Germinated in packets treated with hypochlorite	12	8 spp. germinated out of 12 spp. unsuccessful in Test 1.
5	Germinated in packets treated with hypochlorite	7	No germination of 4 spp.
6	Seeded directly in peat pots	7	No germination of 7 spp.
7	Germinated in packets treated with hypochlorite	15	No germination of 5 spp.; 1 delayed 25 days
8	Seeded in flats with Ky's mixture[a/]	13	No germination of 8 spp. 4 showed good survival for 50 days

a/ Ky's mixture consists of shredded sphagnum moss, vermiculite, perlite and a complete fertilizer.

TABLE 2

AVERAGE HEIGHT AND AREA PER PLANT COVERED BY VINES AT 30 AND 60 DAYS AFTER PLANTING IN TEST NO. 3

Species	No. of Plants	30 days		60 days	
		Ht. (cm)	Area (cm^2)	Ht. (cm)	Area (cm^2)
balsam-apple	4	81	1,215	202	6,713
bean, scarlet runner	2	38	1,178	193	5,308
Black-eyed Susan (T. alata)	1	1	10	10	300
(T. gibsoni)	5	2	16	12	520
cardinal climber	3	2	24	192	2,357
coral-vine	7	5	36	117	817
cypress-vine	7	80	1,830	249	5,914
Flag-of-Spain	1	77	1,617	280	12,320
gourd, Lagenaria	5	59	2,309	349	7,887
gourd, mixed	6	10	306	208	6,139
gourd, Ovifera	12	61	2,775	215	5,687
kudzu	3	2	16	155	1,746
madeira-vine	5	87	1,446	198	2,413
marble-vine	6	68	570	166*	1,911*
moon-vine	4	52	1,262	280	5,320
morningglory	1	1	1	3*	24*
wisteria, blue	4	3	36	44	500

* Data taken at 45 days.

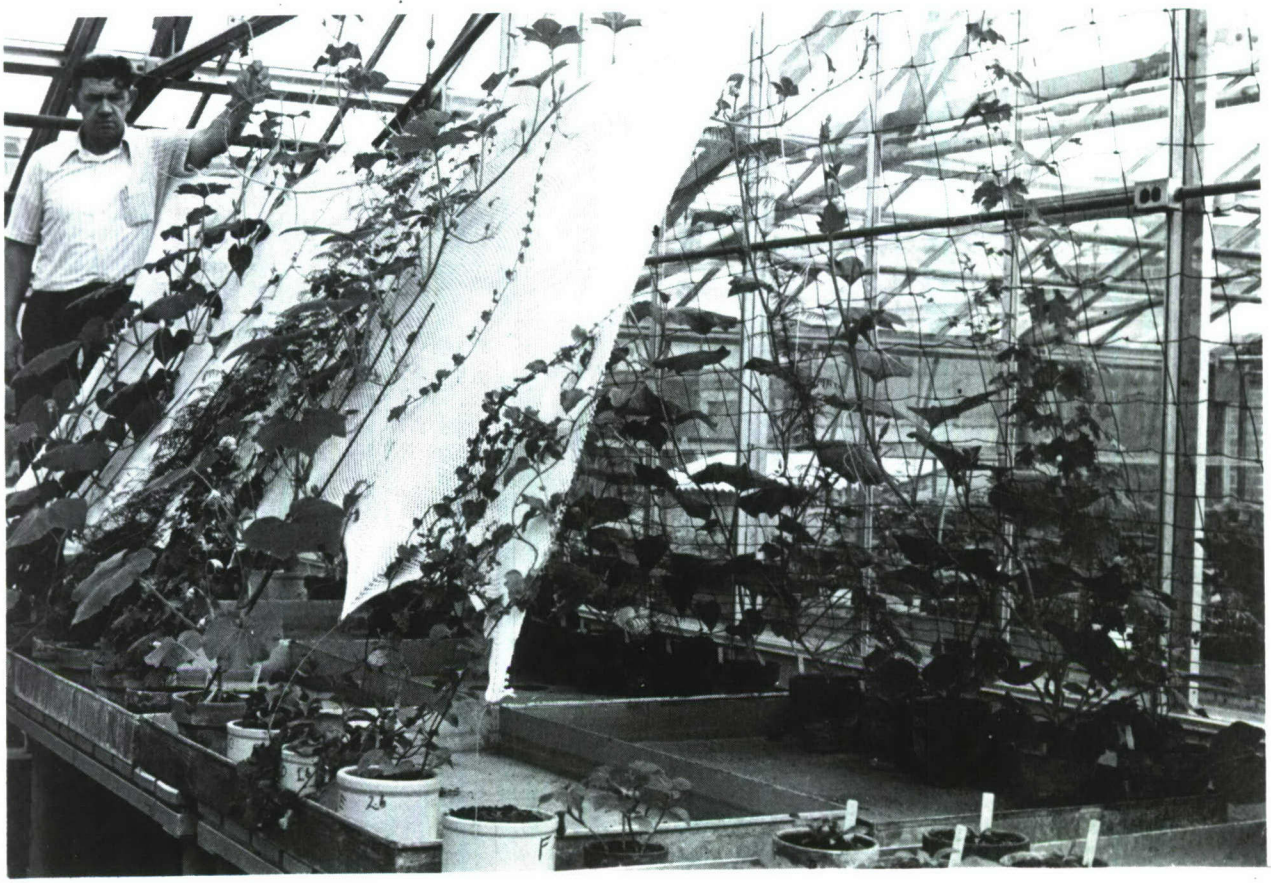

FIGURE 1. Vines 40 days from seed. Gehring style net 3178 - left; American wire fence - right.

FIGURE 2. Vines 60 days from seed. Growing on wire fence.

Tests of Nonsoil Media for Plant Growth.-

During the initial phase of the program, greenhouse tests were conducted to evaluate various media and substrate materials for possible use in establishing vegetation cover on building surfaces, military equipment and other nonsoil areas. Objective of this phase was to determine possible techniques for establishment of a temporary camouflage cover of vegetation on structures to supplement the major program of hydroplanting on disturbed soil surfaces. Tests were conducted from early February to April 1973 under greenhouse conditions.

A synopsis of the materials tested, species, and results follows:

Test 1.

Materials: methyl cellulose, Dacagin (polysaccharide gum) and bacto-agar, each mixed with wood fiber mulch; additional comparison with and without topmulch of wood fiber.
Species: annual ryegrass
Results: methyl cellulose and bacto-agar combined with wood fiber mulch and topmulched with wood fiber gave good growth up to 50 days if fertilized regularly. Other treatments were unsatisfactory after 10 days.

Test 2.

Materials: methyl cellulose, Gelgard M and polyacrylamide, used separately and mixed with three types of wood fiber mulch (Conwed, PFM Fiber and Silva Fiber). All treatments topmulched with wood fiber. Additional tests included top-mulching Styrafoam sheets 1/2" and 1" thick with a wood fiber mulch.
Species: annual ryegrass
Results: satisfactory growth on Gelgard M/wood fiber mulch mixture for 45 days. Other mixtures were successful for 30 days or less. Seedlings on the Styrafoam sheets showed chlorosis after 19 days.

Test 3.

Materials: fiberglass mats 1/4, 1/2 and 1 inch in thickness; topmulched with wood fiber; fertilized daily with Hoagland's solution.
Species: annual ryegrass
Results: after 20 days seedlings in all treatments were showing extensive chlorosis or tip burn.

Test 4.

Materials: polyurethane foam 1/4, 1/2 and 3/4 inch in thickness; topmulched with 3 types of wood fiber mulch.
Species: annual ryegrass
Results: all materials unsatisfactory.

Test 5.

Materials: 50:50 mixture of vermiculite and wood fiber; top-mulched with 3 types of wood fiber alone (Figure 3) or with addition of glycerin or India gum (Ghatti gum); fertilized with Hoagland's solution.
Species: redtop
Results: combinations of vermiculite and wood fiber gave satisfactory growth for 30 to 50 days; addition of glycerin and India gum had no appreciable effect on longevity of growth.

Test 6.

Materials: mixture of vermiculite, Superior wood fiber mulch and Gelgard M in a 1-inch layer on a Gehring-style camouflage net 3178. The same mixture plus India gum was tested on wooden greenhouse flats inclined at an angle of 30 degrees.
Species: redtop
Results: redtop failed to germinate and produce a satisfactory stand with either mixture.

Test 7.

Materials: wood fiber mulch and mixtures containing Gelgard M or India gum in 1-inch layer on Gehring style No. 3178 camouflage netting attached to plastic flats (Figure 4). Duplicate tests included backing with two layers of 4 mil black polyethylene film to prevent evaporation from underneath. The flats were inclined at a 45° angle.
Species: redtop
Results: germination was low on all treatments and seedlings were dead within 16 days. Measurements of daily water applied showed that the addition of black polyethylene film reduced the evaporation. The incorporation of Gelgard M and India gum also reduced water loss. The Gehring netting disintegrated in 20 days.

Test 8.

Materials: 3 polyurethane foams 1/2 inch in thickness were each top-mulched with wood fiber mulch. Foams were Scott Pyrell, Scott Coustex and Acquell.
Species: redtop
Results: no germination within 15 days; test repeated in Test No. 18.

Test 9.

Materials: soil retention blanket consisting of excelsior matting (American Excelsior Co.) overlain on Gehring camouflage netting and top-mulched with wood fiber mulch.
Species: redtop
Results: no germination because of high greenhouse temperatures.

FIGURE 3. Test 5 - Redtop (Agrostis alba) after 35 days. The test media was vermiculite with top mulch of Conwed Hydromulch or Superior Hydromulch.

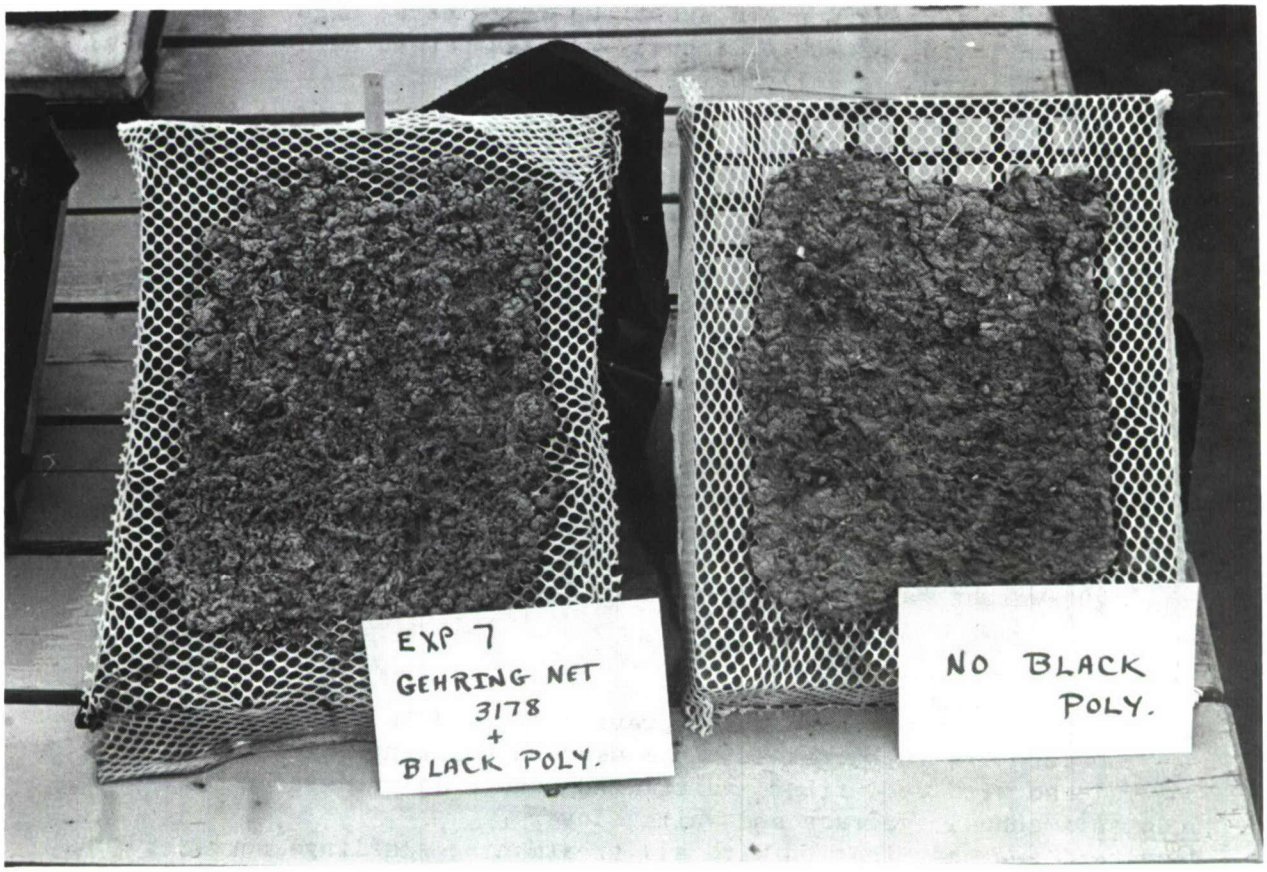

FIGURE 4. Test 7 - Gehring style net 3178 + black polyethylene and Gehring style net alone.

Test 10.

Materials: three types of cotton nap fabric with waterproof backing (Aldan Rubber Co. 2-2796, 9-3344, and 3-0235) overlain on wooden flats with and without Gehring style netting 3178; all treatments top-mulched with wood fiber; flats positioned at 45° angle.
Species: annual ryegrass
Results: good germination and growth up to 20 days; high temperatures unfavorable for growth of annual ryegrass caused early die-off in spite of intensive daily watering.

Test 11.

Materials: Scott Industrial foam, 1/2 inch thick, top-mulched with wood fiber
Species: creeping red fescue
Results: good germination within 10 days but seedlings survived less than 30 days.

Test 12.

Materials: light- and heavy-weight dacron batting, bonded with Mylar polyester film; top-mulched with wood fiber
Species: annual ryegrass and white clover
Results: heavy-weight batting sustained growth for about 25 days; light-weight batting, less than 20 days.

Test 13.

Materials: three urethane foams previously used in Test No. 8 and a Monsanto 1/4-inch urethane foam used in shipping containers; top-mulched with wood fiber; fertilized with Hoagland's solution.
Species: annual ryegrass and white clover
Results: poor germination with all treatments; seedlings survived less than 20 days.

Test 14.

Materials: same as Test No. 9
Species: annual ryegrass and common buckwheat
Results: germination occurred in 5 to 10 days; with the addition of liquid fertilizer, plants remained alive for 60 days.

Test 15.

Materials: Tufcote foam, 1/2 and 3/4 inch in thickness (Specialty Converter Co.); top-mulched with wood fiber.
Species: tall fescue (Kentucky 31) and white clover
Results: white clover germinated in 5 days; tall fescue in 12 days. Both species were in poor condition within 20 days after planting.

In general, limited success was obtained in the establishment and maintenance of satisfactory stands of test species on the nonsoil media tested. Heavy layers of methyl cellulose or bacto-agar mixed with wood fiber mulch were satisfactory for grass seedling development for about 60 days if properly watered and fertilized.

Fiberglass mats, rigid urethane foams and styrafoam materials were unsatisfactory for supporting plant development. Other tests in which various media and mulches were affixed to camouflage netting either suspended alone or provided with a waterproof backing proved to be generally unsatisfactory under the relatively high greenhouse temperatures attained during the test period.

Tests with nonsoil media were terminated in April 1973. In general these greenhouse and laboratory tests indicated that excessive amounts of water were required for establishment and maintenance of satisfactory vegetation cover under field conditions.

Greenhouse Soil Tests with Hydromulch Planting.- Prior to and concurrent with field studies using hydroplanting equipment, preliminary greenhouse tests were conducted in establishment of plant cover on soil substrates using hydromulching techniques.

Three tests were conducted under greenhouse conditions in evaluations of rates of wood-fiber mulch and of various grass-broadleaf species combinations. These tests involved greenhouse propagation benches filled with a greenhouse soil mixture and divided by sheet metal separators into individual plots each 26" x 29" in size. Slurries containing mulch and seed mixtures were applied manually to individual plots.

Greenhouse Soil Test 1.

Objective: determine effects of wood-fiber mulch and polymer thickening agent on plant establishment.

Date: 24 April 1973

Plots: 12 treatments replicated 3 times for total of 36 plots

Variables: 0, 1000, 2000, and 3000 lb/A of wood-fiber mulch applied in soil-seed slurry mixture or as a top-mulch; 0 and 17 lb/acre of thickening agent Gelgard M.

Species Mixture: annual ryegrass, Kentucky 31 fescue, common buckwheat and white clover.

Results: Plantings made in soil alone or with 1000 lb/A of wood-fiber mulch gave relatively poor stands (Figure 5). Mulch mixtures of 2000 and 3000 lb/A gave good coverage in 14 days (Figure 6).

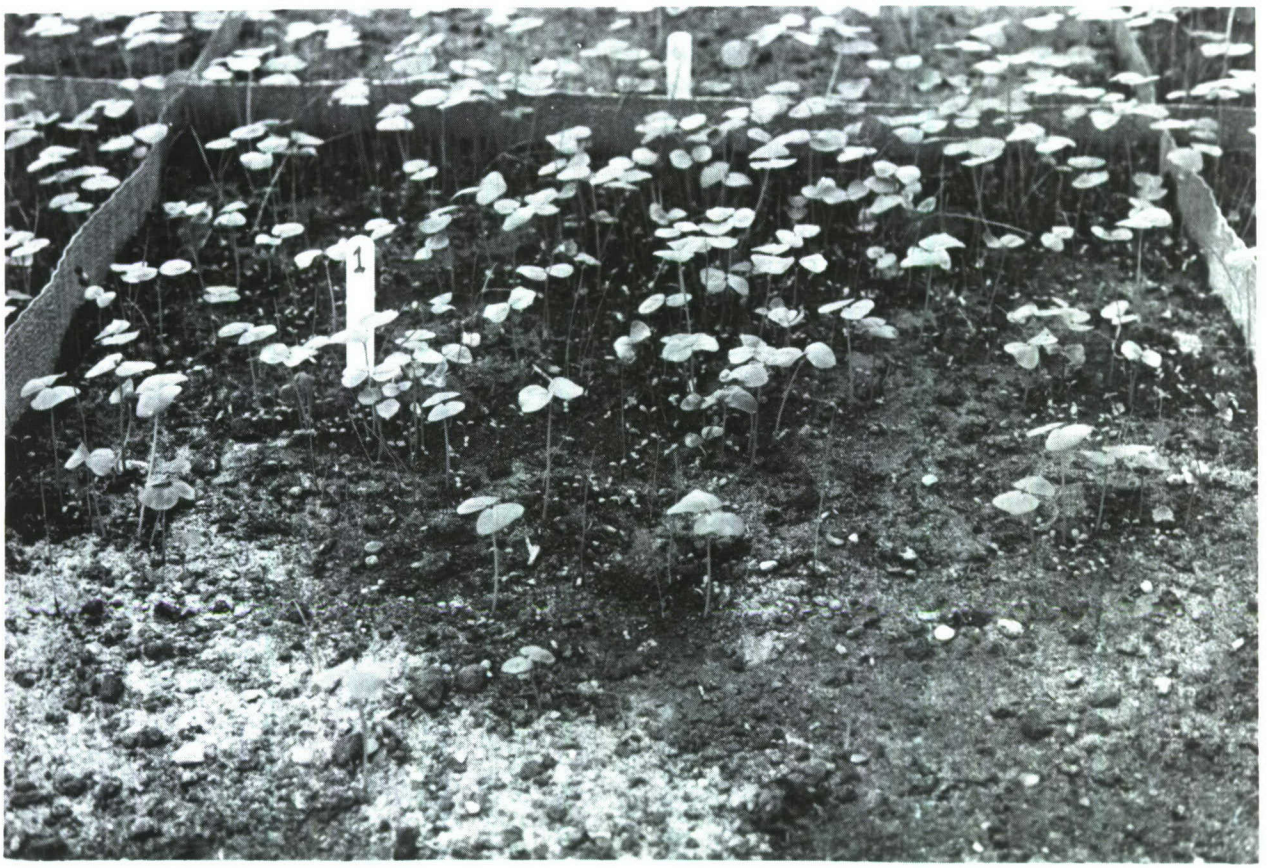

FIGURE 5. Greenhouse Soil Test 1 - Plot 1. Seed mixture annual ryegrass, tall fescue (Kentucky 31), common buckwheat and white clover without top mulch, 6 days after application.

FIGURE 6. Greenhouse Soil Test 1 - Plot 6. Seed mixture annual ryegrass, tall fescue (Kentucky 31), common buckwheat, and white clover with Superior Hydromulch at 2000 pounds per acre, 6 days after application.

Buckwheat dominated all plots within a period of 20 days, the plants reaching a height of 50 cm. in that period (Figures 7 and 8).

Periodic sampling with a probe moisture meter failed to reveal any difference in soil moisture content due to the addition of the thickening agent, Gelgard M.

Greenhouse Soil Test 2.

Objective: evaluation of germination and establishment of various grasses and broadleaf plants following hydromulch planting.

Date: 25 May 1973

Plots: 24 species combinations replicated 3 times for a total of 72 plots.

Variables: 12 species of grass and 7 broadleaf plants in 24 combinations involving one grass and one broadleaf plant each.

Treatment: Hydromulched with 2000 lb/A of wood fiber mulch.

Species Mixtures:

Piper sudan	common buckwheat
weeping lovegrass	Kobe lespedeza
bermudagrass (sprigs)	white clover
carpetgrass (sprigs)	white clover
Clinton oats	common buckwheat
annual ryegrass	field bean
redtop	Kobe lespedeza
Kentucky 31 fescue	blackeyed pea
creeping red fescue	dichondra
Kentucky bluegrass	dichondra
bahia grass	Kobe lespedeza
Proso millet	soybean
Piper sudan	field bean
weeping lovegrass	white clover
bermudagrass	Kobe lespedeza
annual ryegrass	blackeyed pea
carpetgrass	white clover
redtop	white clover
Kentucky 31 fescue	soybean
creeping red fescue	Kobe lespedeza
bahia grass	Kobe lespedeza
Proso millet	field beans
Clinton oats	soybean

Results: Overall photographs of the test at 5, 10, 17 and 21 days are shown in Figures 9 to 12.

FIGURE 7. Greenhouse Soil Test 1 - Soil plots 26" x 29", 20 days after application.

FIGURE 8. Greenhouse Soil Test 1 - Soil plots dominated by common buckwheat 20 days after application.

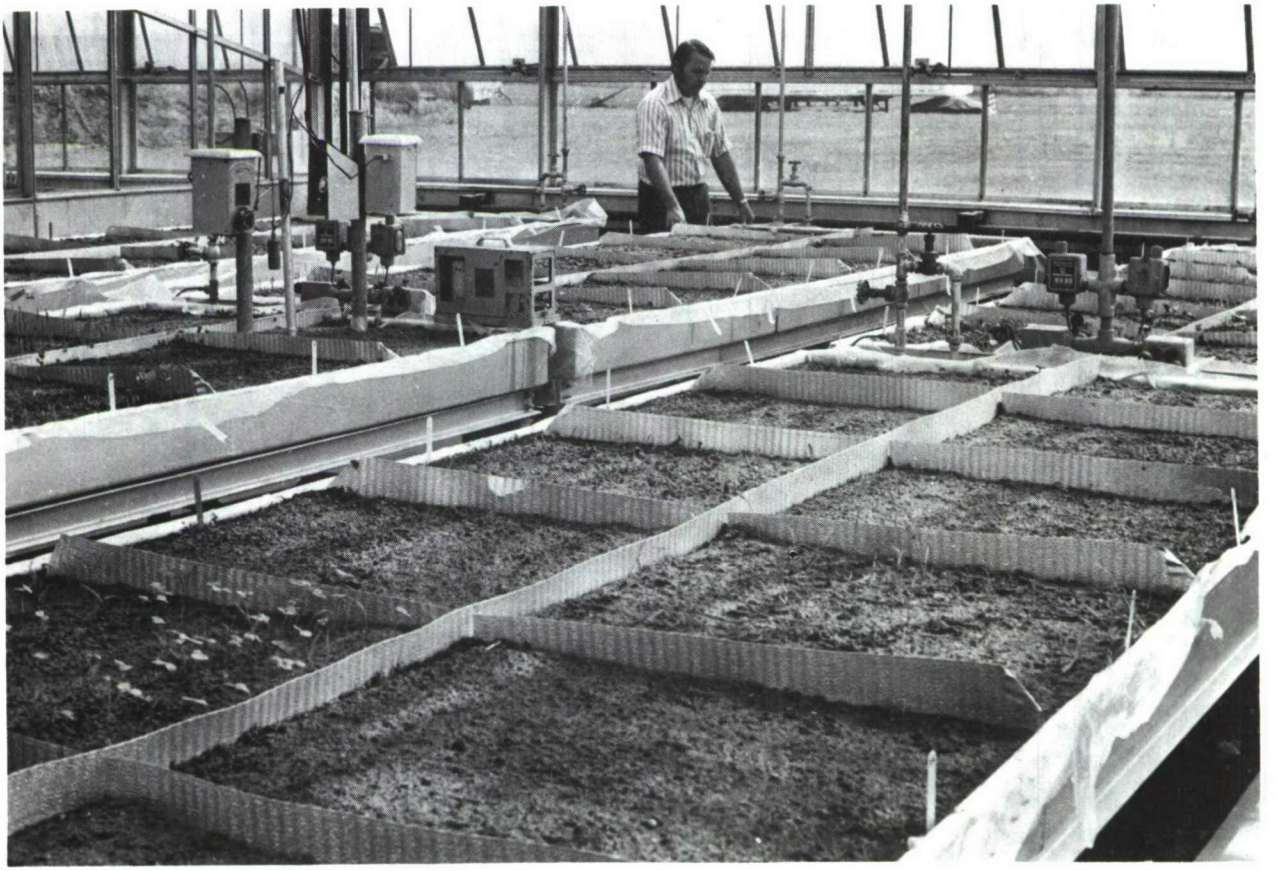

FIGURE 9. Overall view of Greenhouse Soil Test 2 at 5 days.

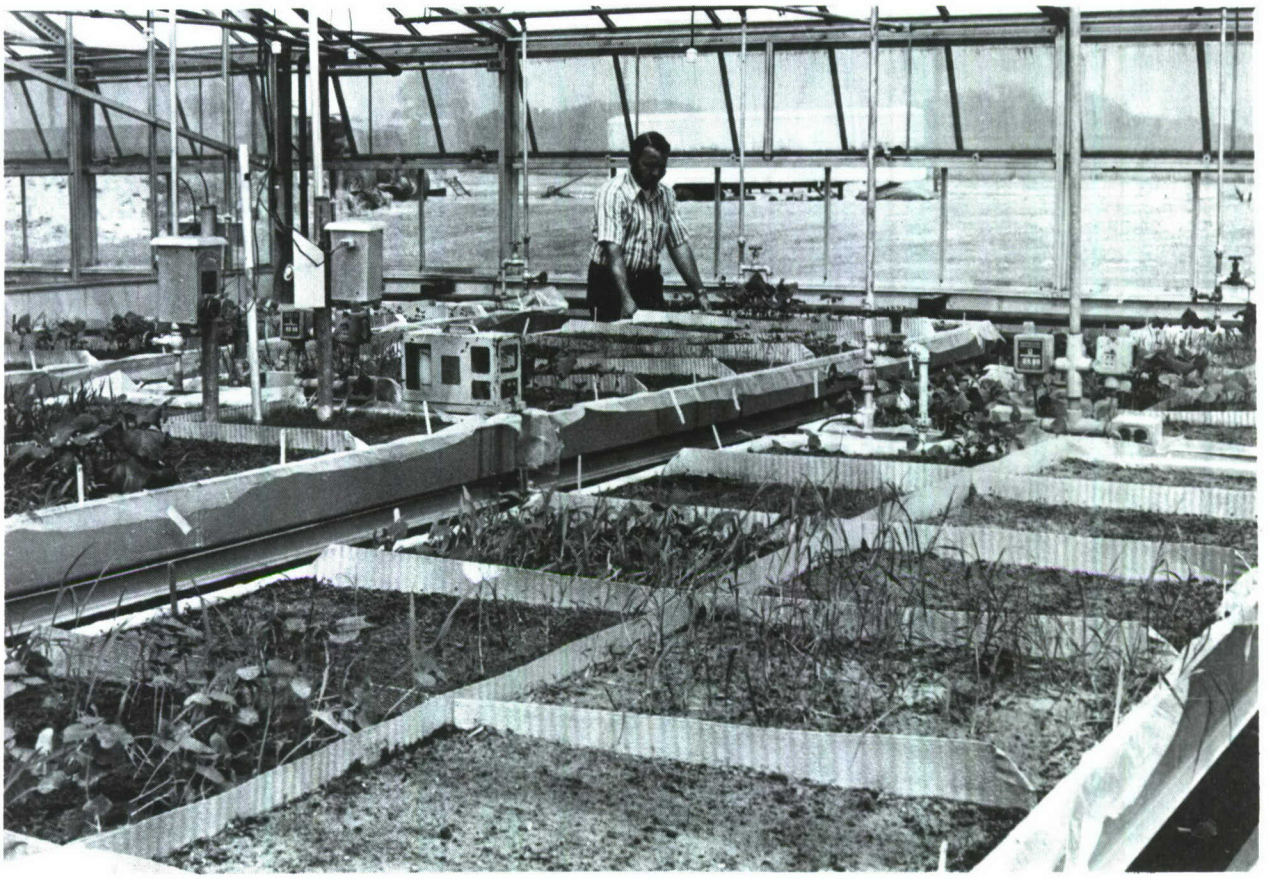

FIGURE 10. Overall view of Greenhouse Soil Test 2 at 10 days.

FIGURE 11. Overall view of Greenhouse Soil Test 2 at 17 days.

FIGURE 12. Overall view of Greenhouse Soil Test 2 at 21 days.

The most rapid establishment and effective stand density was obtained with the following grasses: Piper sudan, weeping lovegrass (Figure 13), bermudagrass from sprigs (Figure 14), Proso millet, redtop (Figure 15), annual ryegrass and creeping red fescue.

The most actively growing broadleaf plants were Kobe lespedeza, blackeyed peas, field beans, white clover, buckwheat, and soybean (Figure 16).

Greenhouse Soil Test 3.

Objective: evaluation of germination and establishment of various species combinations from hydromulch planting under high temperature and greenhouse conditions.

Date: 17 July 1973

Plots: 24 species combinations replicated 3 times for a total of 72 plots.

Variables: 11 species of grasses, 9 broadleaf herbaceous plants and 5 vines.

Treatment: hydromulched with 2,000 lb/A of wood-fiber mulch.

Species Mixtures:

bermudagrass	Kobe lespedeza
Proso millet	hairy indigo
weeping lovegrass	cypress-vine
sorghum-sudan hybrid	gourds, mixed
buckwheat	sesbania
Argentine bahia	combine peas
sorghum-sudan hybrid	gourds, Ovifera
Proso millet	balsam-apple
Piper sudan	gourds, Ovifera
Proso millet	cypress-vine
Clintland oats	balsam-apple
rice	field beans
corn	soybean
pearl millet	gourd, Lagenaria
pearl millet	susbania
sorghum-sudan hybrid	gourd, Lagenaria
rice	hairy vetch
Piper sudan	combine peas
sorghum-sudan hybrid	hairy indigo
rice	Kobe lespedeza
weeping lovegrass	combine peas
weeping lovegrass	hairy indigo
Piper sudan	rape
centipedegrass	Kobe lespedeza

FIGURE 13. Greenhouse Soil Test 2 - Weeping lovegrass at 30 days.

FIGURE 14. Greenhouse Soil Test 2 - Bermudagrass (sprigs) at 21 days.

FIGURE 15. Greenhouse Soil Test 2 - Redtop and white clover at 26 days.

FIGURE 16. Greenhouse Soil Test 2 - Sudan grass and buckwheat at 26 days.

Results: Weeping lovegrass (Figure 17), sorghum-sudan hybrid, Proso millet and Piper sudan gave good cover in a short period of time. Rape was the best of the broadleaf plants. Buckwheat and mixed gourds were also rapid in establishment of cover.

Maximum yields as measured by fresh weight/plot at 45 days were produced by combinations involving sorghum-sudan hybrid and Piper sudan.

In summary, these tests were useful in establishing the general rate requirement for mulch application (in excess of 1000 lb/acre) and in providing preliminary evaluations of plant species for use in field trials. Soil Test 2, initiated on 25 May under moderate temperature conditions, provided selections of both warm- and cool-season grasses. Soil Test 3, conducted in midsummer, emphasized principally warm-season species.

Field Tests with Hydromulching Equipment

Major effort was devoted to field tests of the feasibility of hydroplanting techniques for the rapid establishment of vegetation cover on denuded soil areas. With the exception of the initial test, conducted by contract equipment, all plantings were made with a Bowie Victor Model 500-gallon Hydromulcher, trailer mounted, using an Allis Chalmers Model CA tractor. Figures 18, 19 and 20 show the general features of this equipment and its operation. A general description of hydroplanting equipment is given in Appendix B.

Field tests were conducted at two locations:

Area I. Vegetation Control Division agricultural area, Fort Detrick

Soil is classified as Duffield silt loam (1), characterized by silt loam topsoil and silty clay loam subsoil, derived from limestone. These soils are fertile and considered highly productive.

Topography was level or gently sloping (maximum 3 percent).

Site conditions: used for agricultural crops on a 3- or 4-year rotation; fallow prior to site preparation for these tests.

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(1) Soil survey Frederick County, Maryland. Series 1956, No. 15

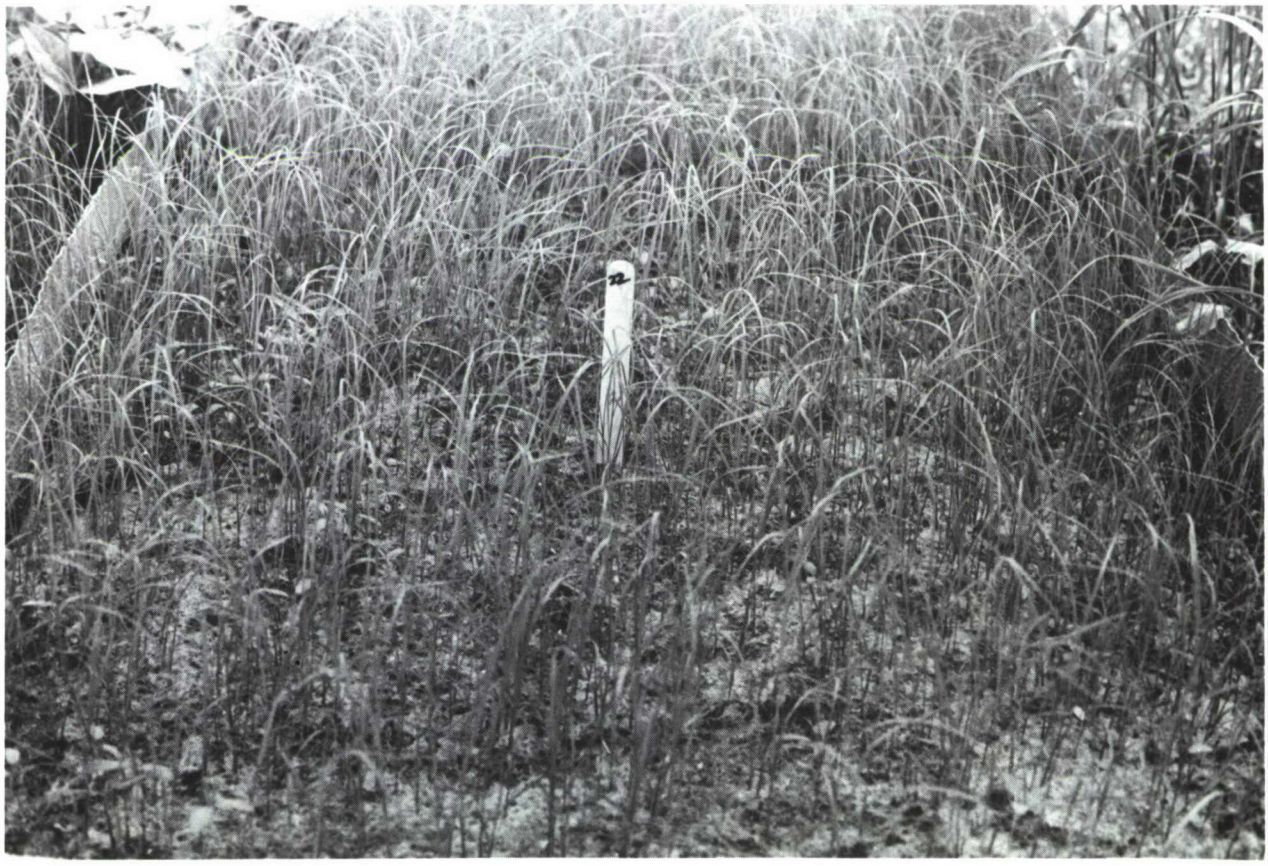

FIGURE 17. Greenhouse Soil Test 3 - Plot 22. Weeping lovegrass at 13 days.

FIGURE 18. Bowie Hydromulcher - 500-gallon Victor model (front).

FIGURE 19. Bowie Hydromulcher - 500-gallon Victor model (back).

FIGURE 20. Field Test 3 - Bowie Hydromulcher during spray application with hose.

Area II. Grid area, Fort Detrick

Soil is classified as Hagerstown rocky loam, characterized by deep, well-drained soils, mostly derived from limestone.

Topography was gently sloping (maximum 8 percent).

Site conditions: the specific area for test plots consisted of a landfill with yellowish-red, heavy clay loam subsoil recently spread on surface and compacted. The site was graded prior to tests to remove weedy vegetation.

Climatic conditions during the test period included an early summer period with frequent heavy thunderstorms. Late summer conditions were relatively hot and dry. Table 3 presents a summary of precipitation data recorded at Area I, with the associated dates of field test plantings.

Following are detailed descriptions of the field tests which were initiated 29 May and continued until 30 September 1973.

Field Test 1

Objective: determine effects of discing vs nondiscing prior to hydroplanting on two soil types.

Date: 29 May 1973

Sites: Area I and Area II

Plots: 20 x 40 ft; two replications; total of four plots

Variables: discing 3 days prior to planting vs nondiscing
soil type: Duffield silt loam (Area I) and Hagerstown rocky loam (Area II)

Treatment: Hydroplant with Reinco Hydrograsser 10 (contract)
Slurry mixture: 585 lb/A of Conwed mulch; 320 lb/A of 10-10-10 fertilizer; 2,000 gal/A water

Species: Mixture of buckwheat, tall fescue, annual ryegrass, Kentucky bluegrass, and white clover

Post-planting Conditions: 3 irrigations applied in 14-day period; precipitation of 0.9 inch with high winds one week after planting caused severe washing and erosion of mulch at Area II.

Results: Emergence of most species in 14 to 22 days at Area I; poor establishment at Area II.

Buckwheat dominated plots on Area I for first 90 days; weeds

then became prevalent in midsummer; at 120 days the cool-season grasses (tall fescue and Kentucky bluegrass) began to assume dominance. Figures 21 and 22 show the established stands of buckwheat and grass mixture at 27 and 43 days, respectively, after hydroplanting in Area I.

On Area II the heavy rain and subsequent severe washing resulted in little or no survival; plots were discontinued after 3 weeks.

TABLE 3

PRECIPITATION DURING THE EXPERIMENTAL PERIOD AND DATES OF FIELD TEST APPLICATION

Date	Precipitation (inches)	Field Test
May 29		1
Jun 6	Tr.	
7	0.90	
17	Tr.	
18	0.10	
21	0.60	
22	0.40	
23	0.70	
27	0.20	
28	0.10	2
Jul 2	1.50	3
9	1.50	
11	0.05	
16 (12 + 15)	0.22	
17	0.60	
19		4
20	0.12	
27-29	0.10	
Aug 1		5
3		6
6	0.42	
7		7
8		8
13	0.36	
15	0.12	
17		9
20	1.75	
21	0.90	
Sep 4	0.63	
14	3.90	
29	0.40	

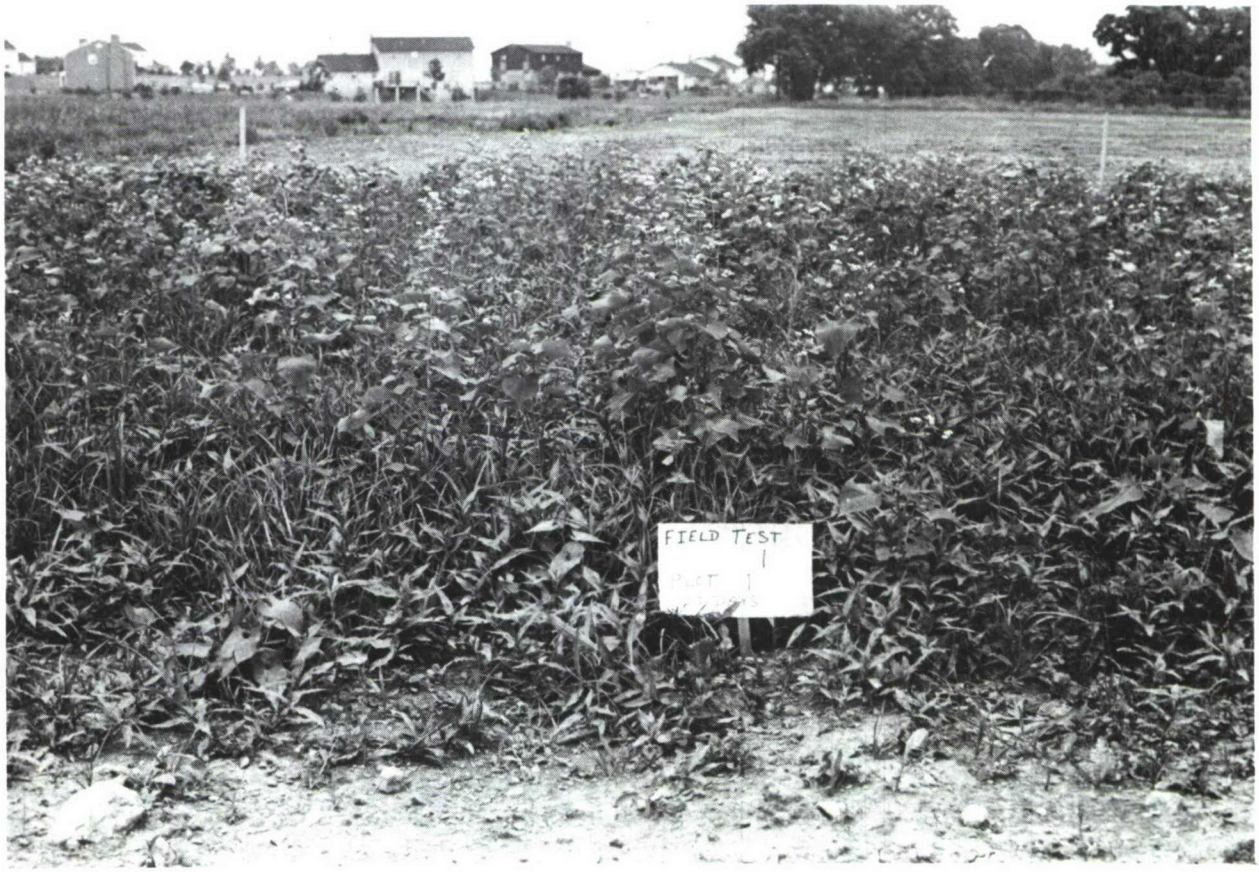

FIGURE 21. Field Test 1 on good soil at 27 days. Buckwheat, grass mixture.

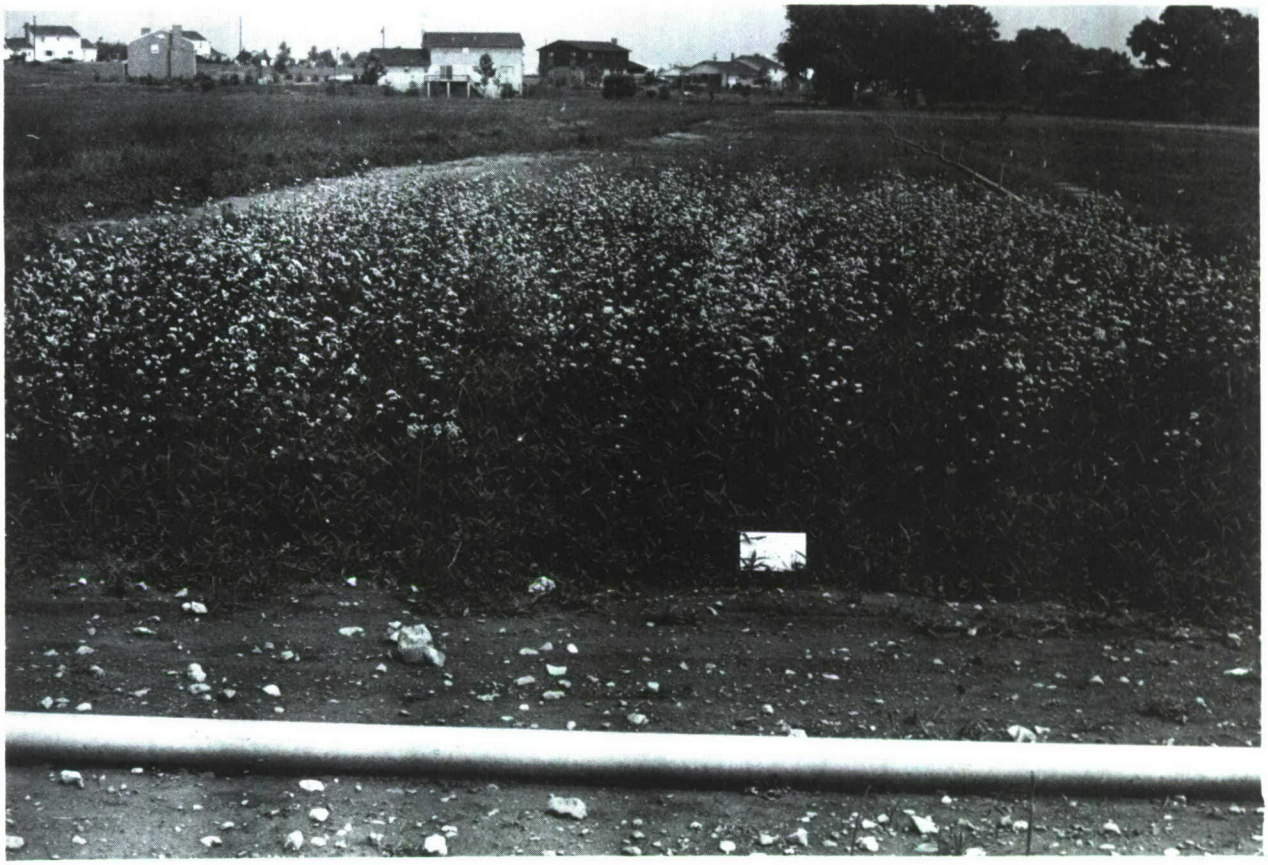

FIGURE 22. Field Test 1 on good soil at 43 days. Buckwheat, grass mixture.

Field Test 2

Objective: determine the effects of mulch rate on establishment of two seed mixtures

Date: 28 June 1973

Site: Area I

Plots: 20 x 30 ft; two and four replications; total of 12 treatments plus untreated control

Variables: 900 and 1,500 lb/A wood fiber mulch (PFM)
species mixtures

Treatment: Hydroplant with Bowie Hydromulcher
Slurry mixture: 900 or 1,500 lb/A of mulch; 800 lb/A of 10-10-10 fertilizer; 3,000 gal/A water
All plots disced 2 weeks prior to hydroplanting

Species: 1. Sorghum-sudan hybrid and sweetclover
2. Annual ryegrass and white clover

Post-planting Conditions: Heavy rain (1.4 inches) occurred less than 24 hours after planting resulting in severe washing and erosion of mulch-seed mixture.

Results: Sorghum-sudan hybrid germinated in 5 to 7 days; at 30 days stands gave 40 to 70% coverage. By 60 days plants were 7 ft. tall. Annual ryegrass gave 50 to 60% coverage in 30 days; by midsummer the stands were suppressed by heavy growth of weeds.
Neither sweetclover or white clover became established.

Figures 23 to 25 show the development of sorghum-sudan hybrid and annual ryegrass at 30 to 73 days after hydroplanting.

Field Test 3

Objective: determine effects of mulch rate on several species combinations

Date: 2 July 1973

Site: Area I (See Figure 26)

Plots: 20 x 30 ft.; two replications; total of 56 plots

Variables: 900 and 1,500 lb/A wood fiber mulch
14 species combinations

FIGURE 23. Field Test 2 - Sorghum-sudan hybrid 30 days after application.

FIGURE 24. Field Test 2 - Sorghum-sudan hybrid 73 days after application with foxtail millet in the foreground.

FIGURE 25. Field Test 2 - Annual ryegrass 30 days after application.

FIGURE 26. Field Test 3 - Soil disced prior to test (same day) - foreground, no mulch; background (dark area), mulched immediately before photographed.

Treatment: Hydroplant with Bowie Hydromulcher
Slurry mixture: 900 or 1,500 lb/A of wood fiber mulch; 1,500 lb/A of 10-10-10 fertilizer; 3,000 gal/A water

Species Mixtures:

Warm-season grasses
- Argentine bahia + Kobe lespedeza
- bermudagrass + hairy indigo
- Proso millet + white clover
- weeping lovegrass + crimson clover
- sorghum-sudan hybrid (FFR 66) + buckwheat
- sorghum-sudan hybrid (FFR 66) + cowpea
- foxtail millet + soybean

Cool-season grasses
- annual ryegrass + rape
- perennial ryegrass + hairy vetch
- creeping red fescue + white clover
- redtop + white clover
- Clinton oats + bush beans
- Kentucky 31 fescue + alfalfa
- Kentucky bluegrass + dichondra

Post-planting Conditions: Rainfall of 1.50 inches occurred on the day of planting and an additional 1.5 inches was recorded during the following week. Plots were irrigated on a regular basis.

Results:

Comparison of the species mixtures showed significant differences in establishment and height growth due to the seasonal adaptability of the grass components. Warm-season grass mixtures averaged 71.4% stand density at 60 days in contrast to 30.2% density for cool-season grasses. Best establishment in this test was achieved by sorghum-sudan hybrid + cowpea (100%), foxtail millet + soybean (96.2%), and Proso millet + white clover (92.5%). In the cool-season group, Clinton oats + bush beans was the most successful mixture (75% stand density and average height of 66 cm at 60 days). Figures 27 through 31 show the establishment of foxtail millet and Proso millet-white clover mixture at various stages of development. (See Table 4).

Examination of the effects of mulch rate (900 vs 1500 lb/A) shows only a slight increase in height growth of warm-season and cool-season grasses (+ 2.0 and + 3.6 cm, respectively).

The proportion of grasses to broadleaf plants was slightly reduced by the addition of mulch in both groups (- 4.5% for warm-season and - 3.14% for cool-season species).

FIGURE 27. Field Test 3 - Foxtail millet 25 days after application.

FIGURE 28. Field Test 3 - Foxtail millet 73 days after application (foreground).

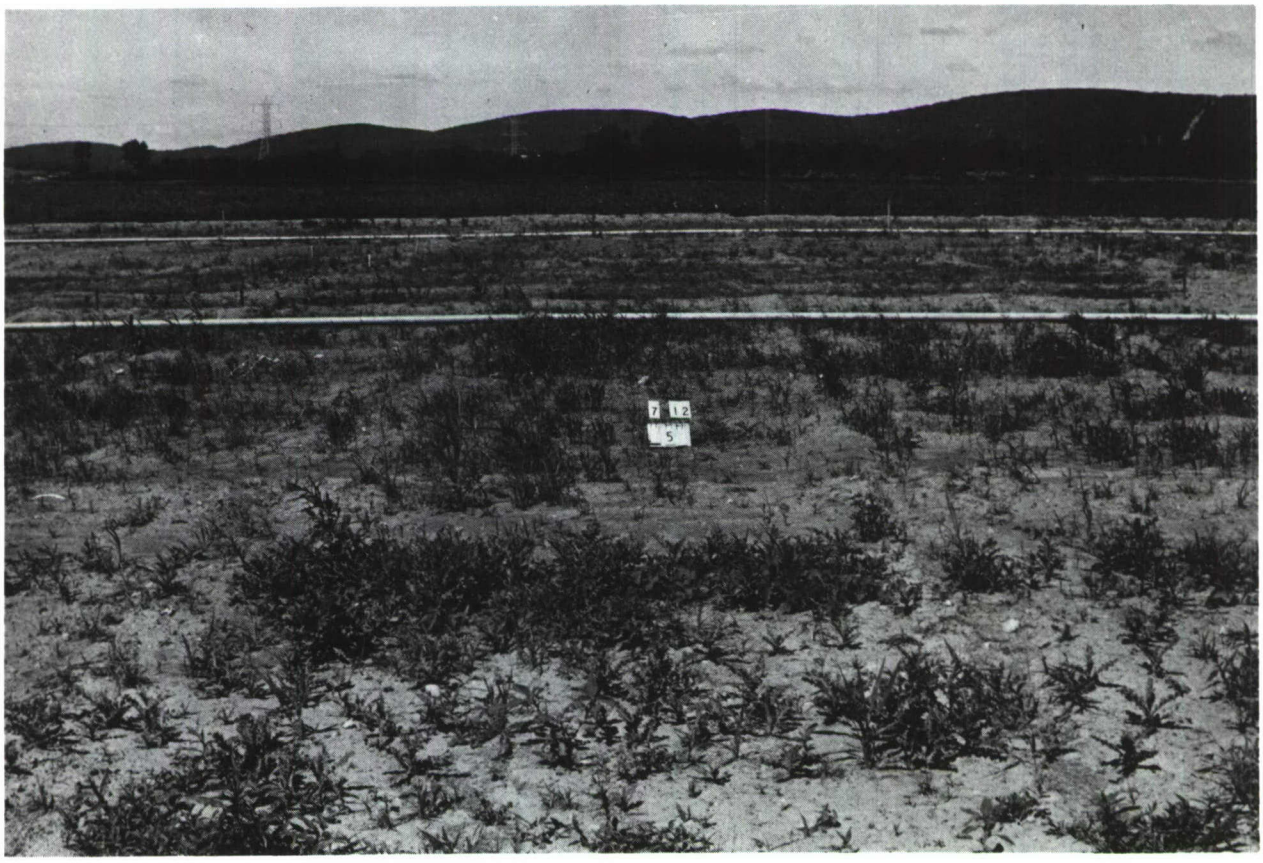

FIGURE 29. Field Test 3 - Proso millet and white clover 10 days after application.

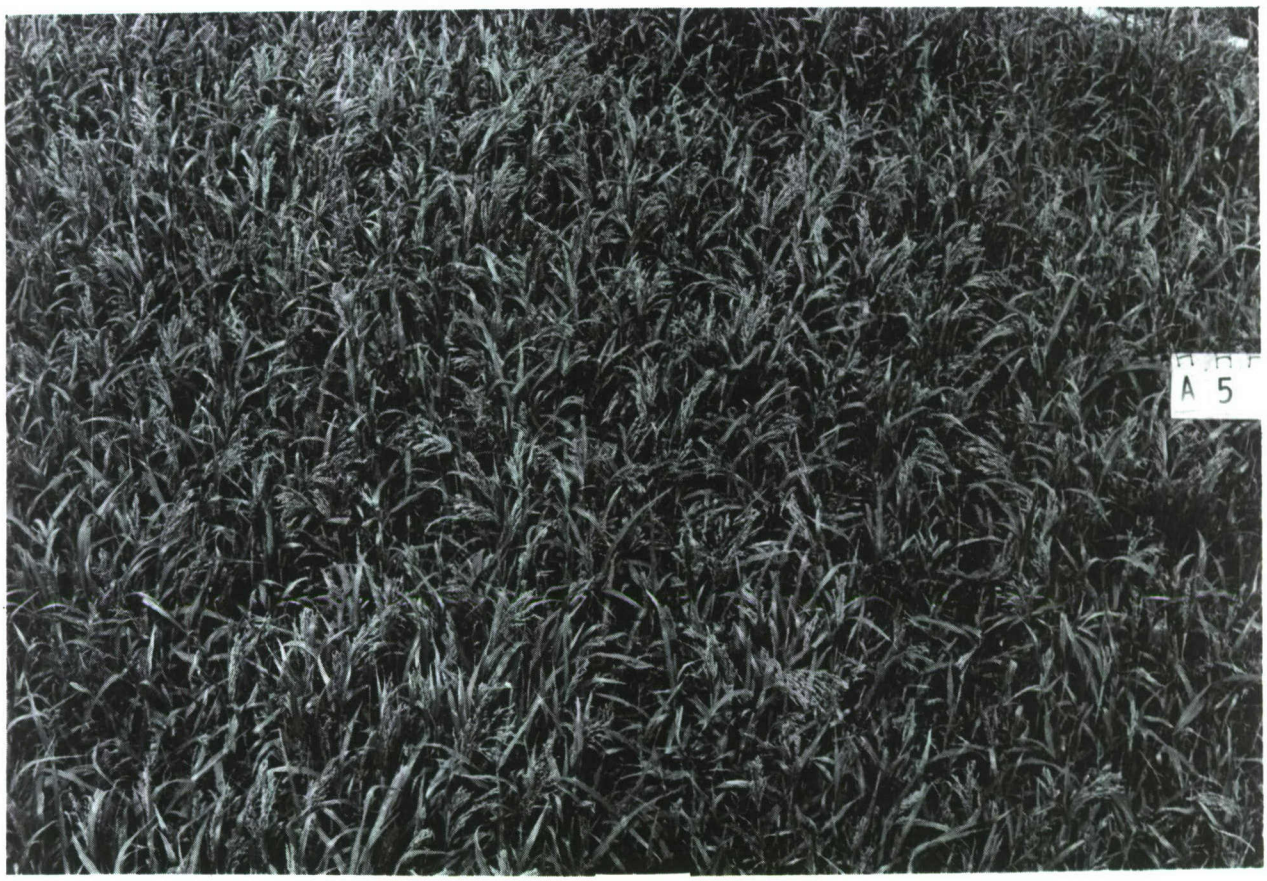

FIGURE 30. Field Test 3 - Proso millet and white clover 34 days after application.

FIGURE 31. Field Test 3 - Proso millet and white clover 73 days after application.

Some of the broadleaf components failed to become established under the conditions of the test: crimson clover, soybean, dichondra, cowpea, and white clover in mixture with Proso millet. Buckwheat, rape and hairy vetch were among the better species in emergence and establishment. Maximum cover (32.5%) was attained by buckwheat on plots receiving 1500 lb/A of mulch. Broadleaf plants averaged slightly higher in percent composition and height growth as a result of higher mulch rates.

TABLE 4

PERCENT COVER AND PLANT HEIGHT (CM) AT 60 DAYS OF THE SPECIES COMPONENTS OF FIELD TEST 3 RANKED IN ORDER OF PERCENT COVER OF WARM- AND COOL-SEASON GRASSES

Grass	% Cover	Ht (cm)	Broadleaf	% Cover	Ht (cm)
		Warm-season			
sorghum-sudan	100	202	cowpea	0	0
foxtail millet	96	102	soybean	0	0
Proso millet	92	69	white clover	0	0
sorghum-sudan	74	195	buckwheat	26	80
bermudagrass	64	40	hairy indigo	0.3	7
weeping lovegrass	54	52	crimson clover	0	0
Argentine bahia	17	4	Kobe lespedeza	3	14
		Cool-season			
Clinton oats	75	66	bush beans	0.5	10
annual ryegrass	39	64	rape	19	52
redtop	32	18	white clover	9	15
Kentucky 31 fescue	31	22	alfalfa	12	22
perennial ryegrass	18	34	hairy vetch	20	50
creeping red fescue	16	17	white clover	8	15
Kentucky bluegrass	0	0	dichondra	0	0

Field Test 4

Objective: determine the effects of soil stabilizers and mulch rates on establishment of a warm-season mixture

Date: 19 July 1973

Site: Area II

Plots: 20 x 30 ft.; two replications; total of 8 plots

Variables: 1,500 and 3,000 lb/A of wood fiber mulch
Curasol AE soil stabilizer at 0 and 45 gal/A

Treatment: Hydroplant with Bowie Hydromulcher
Slurry mixture: 4 combinations of mulch and soil stabilizer; 750 lb/A of 10-10-10 fertilizer and 3,000 gal/A of water

Species: Mixture of sorghum-sudan hybrid (FFR 66), Proso millet and rape

Pretreatment conditions: all plots graded and double-disced two ways immediately prior to hydroplanting.

Post-planting conditions: plots irrigated at 2- to 3-day intervals for initial two weeks and subsequently at three longer intervals with the addition of 14 lb/A of 20-20-20 fertilizer.

Results: Sorghum-sudan hybrid assumed dominance of all treatments with only a small quantity of Proso millet and rape becoming established. Percent stand cover at 30 days and average height (cm) at 60 days are shown in the following summary:

	% stand at 30 days	Ht.(cm) at 60 days
1500 lb/A mulch	82	90
3000 lb/A mulch	91	87
1500 lb/A mulch + Curasol at 45 gal/A	84	100
3000 lb/A mulch + Curasol at 45 gal/A	98	115

Figures 32 through 36 show the establishment of above plots receiving 3000 lb/A of mulch and Curasol AE and 3000 lb/A of mulch without Curasol AE.

FIGURE 32. Field Test 4 - Plot 3, 4 days after application. Sorghum-sudan, rape and Proso millet.

FIGURE 33. Field Test 4 - Plot 3, 12 days after application. Sorghum-sudan, rape, and Proso millet.

FIGURE 34. Field Test 4 - Plot 3, 55 days after application (after irrigation). 3000 lbs of mulch and Curasol AE - Sorghum-sudan, rape, and Proso millet.

FIGURE 35. Field Test 4 - Plot 6, 55 days after application. 3000 lbs of mulch - no soil additive. Sorghum-sudan, rape, and Proso millet.

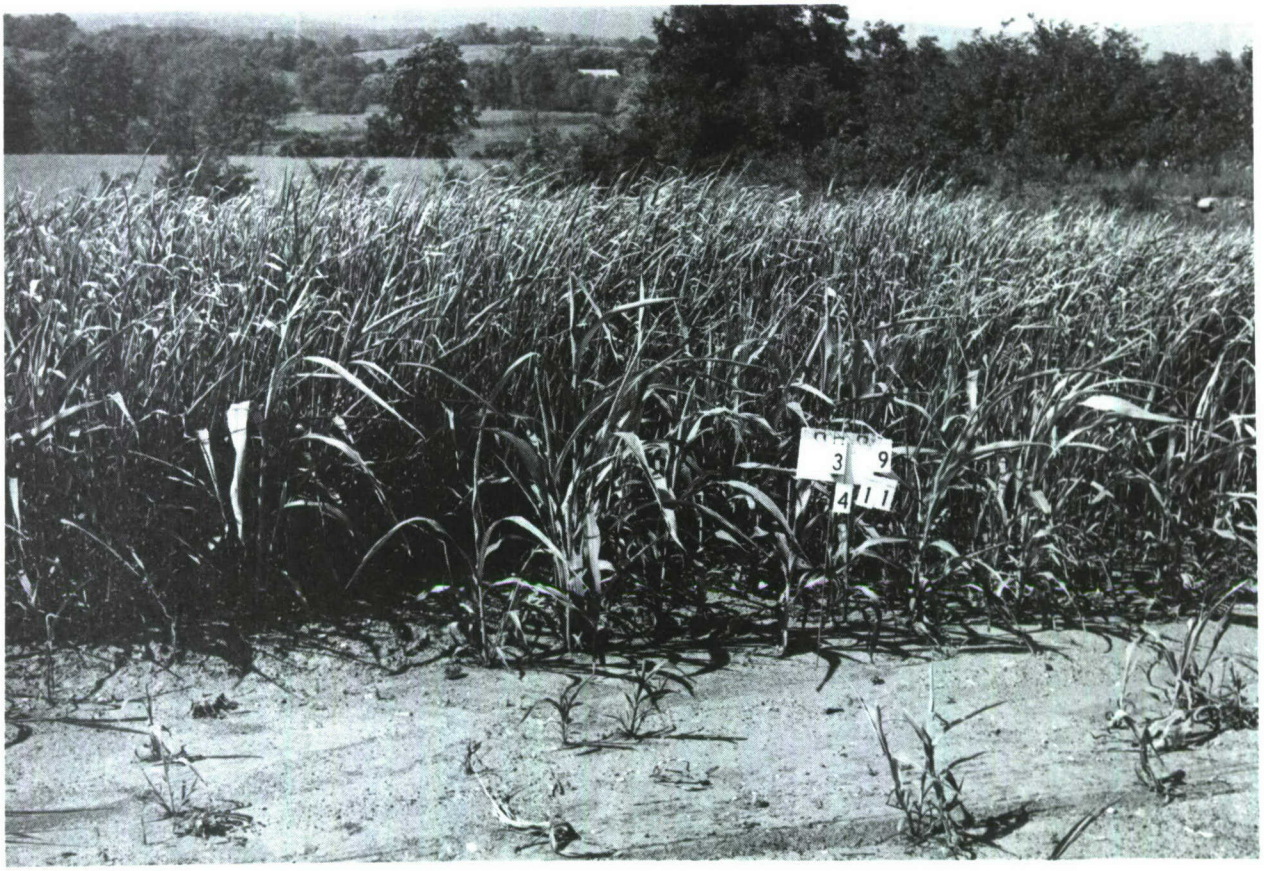

FIGURE 36. Field Test 4 - Plot 3, 53 days after application (before irrigation). 3000 lbs of mulch and Curasol AE. Sorghum-sudan, rape and Proso millet.

Field Test 5

Objective: determine the effects of discing, seeding methods and cultipacking on establishment of a warm-season mixture.

Date: 1 August 1973

Site: Area I

Plots: 20 x 30 ft.; three replications; total of 12 treatments and 36 plots

Variables: discing vs nondiscing prior to seeding
seeding by broadcast, Brillion seeder and hydroplanting
cultipacker and hydromulching after seeding

Treatments:

1. Disc - hand seed - cultipack
2. Nondisc - hand seed - cultipack
3. Disc - hand seed - mulch & fertilizer
4. Nondisc - hand seed - mulch & fertilizer
5. Disc - Brillion seeder - mulch & fertilizer
6. Nondisc - Brillion seeder - mulch & fertilizer
7. Disc - Brillion seeder
8. Nondisc - Brillion seeder
9. Disc - mulch & fertilizer & seed - cultipack
10. Nondisc - mulch & fertilizer & seed - cultipack
11. Disc - mulch & fertilizer & seed
12. Nondisc - mulch & fertilizer & seed

Hydromulch treatments were applied by Bowie Hydromulcher with 500 lb/A of 10-10-10 fertilizer and 3,000 gal/A water

Species: mixture of sorghum-sudan hybrid (FFR-66), Proso millet and rape.

Post-planting Conditions: Rainfall of 0.60 inch occurred on day following planting. Irrigated as necessary for establishment.

Results: Observations at one week showed good to excellent emergence from hand seeding and hydroplanting. Brillion seeder treatments rated poor to fair in stand establishment.

At 30 days total stand density exceeded 90% for both hand-seeded and hydroplanted areas (92.8 and 91.5%, respectively); percent cover on Brillion seeder treatments averaged 73.6%. Disced plantings averaged 90.4% cover at 30 days versus 83.3% cover for nondisced treatments.

At 70 days, height measurements of sorghum-sudan hybrid were 159.6 cm on disced plots compared with 142.5 cm on nondisced areas. Rape showed no difference in height at this period.

Table 5 summarizes percent stand densities at 30 days for individual treatments.

TABLE 5

PERCENT STAND DENSITY FOR INDIVIDUAL TREATMENTS AT 30 DAYS IN FIELD TEST 5

Treatment	Disc	Nondisc
Hand seeding		
plus cultipacker	93.0	88.3
plus mulch	98.3	91.6
Brillion seeder		
plus mulch	90.0	70.0
without mulch	73.0	61.6
Hydroplanting		
plus cultipacker	98.3	96.6
without cultipacker	90.0	91.6

Mechanical seeding with the Brillion Seeder without mulch gave relatively poor stands. The addition of mulch following hand seeding and mechanical seeding resulted in increased stand density. Post-planting treatment with cultipacker on hand-seeded and hydroplanted areas has no advantage in stand establishment.

Figures 37 through 39 show the establishment of vegetation 43 days after planting by hydromulcher, hand seeding, and Brillion seeder.

Field Test 6

Objective: determine the effects of mulch rate and soil stabilizer on establishment of bermudagrass sprigs.

Date: 3 August 1973

Site: Area I

Plots: 20 x 30 ft; single replicate; total of 8 plots

Variables: 1500 and 3000 lb/A of mulch applied with sprigs or as top-mulch; Curasol AE soil stabilizer at 0 and 45 gal/A

FIGURE 37. Field Test 5 - Hydromulcher, not disced, 43 days after application.

FIGURE 38. Field Test 5 - Plot 5. Hand seeded, not disced, 43 days after application.

FIGURE 39. Field Test 5 - Brillion seeder, disced, 43 days after application.

Treatments:

1. Sprigs applied in water; topmulch at 1500 lb/A
2. Sprigs applied in water; topmulch at 3000 lb/A
3. Sprigs applied in 1500 lb/A mulch; no topmulch
4. Sprigs applied in 1500 lb/A mulch; topmulch at 1500 lb/A
5. Sprigs applied in water with 45 gal/A Curasol; topmulch at 1500 lb/A
6. Sprigs applied in water with 45 gal/A Curasol; topmulch at 3000 lb/A
7. Sprigs applied in water with 45 gal/A Curasol and 1500 lb/A mulch
8. Sprigs applied in water with 45 gal/A Curasol and 1500 lb/A mulch; topmulch at 1500 lb/A

All treatments received bermudagrass sprigs at 4 bu/1000 sq. ft.; 500 lb/A of 10-10-10 fertilizer, and water at 3,000 gal/A.

Species: common bermudagrass

Post-planting Conditions: plots received three irrigations during the week following planting.

Results:

At 30 days bermudagrass had become established on all plots with a percent cover of 30 to 75%; weed competition was severe and an overstory of weeds soon dominated the plots. At 30 days, plots receiving Curasol had a slightly better cover of bermudagrass than those with mulch alone.

Figures 40 and 41 show the general development of bermudagrass from 2 days to 36 days after hydroplanting.

Evaluations at 75 days showed a definite advantage with the addition of Curasol as shown in the tabulation using pooled mulch and topmulch treatments. No consistent trends could be observed due to mulch vs topmulch.

	Percent ground cover		Weight of weeds
	bermudagrass	weeds	(lb/plot)
1500 lb/A mulch	67.5	85	49.5
3000 lb/A mulch	72.5	70	36.0
1500 lb/A mulch + Curasol	87.5	70	47.1
3000 lb/A mulch + Curasol	82.5	75	46.6

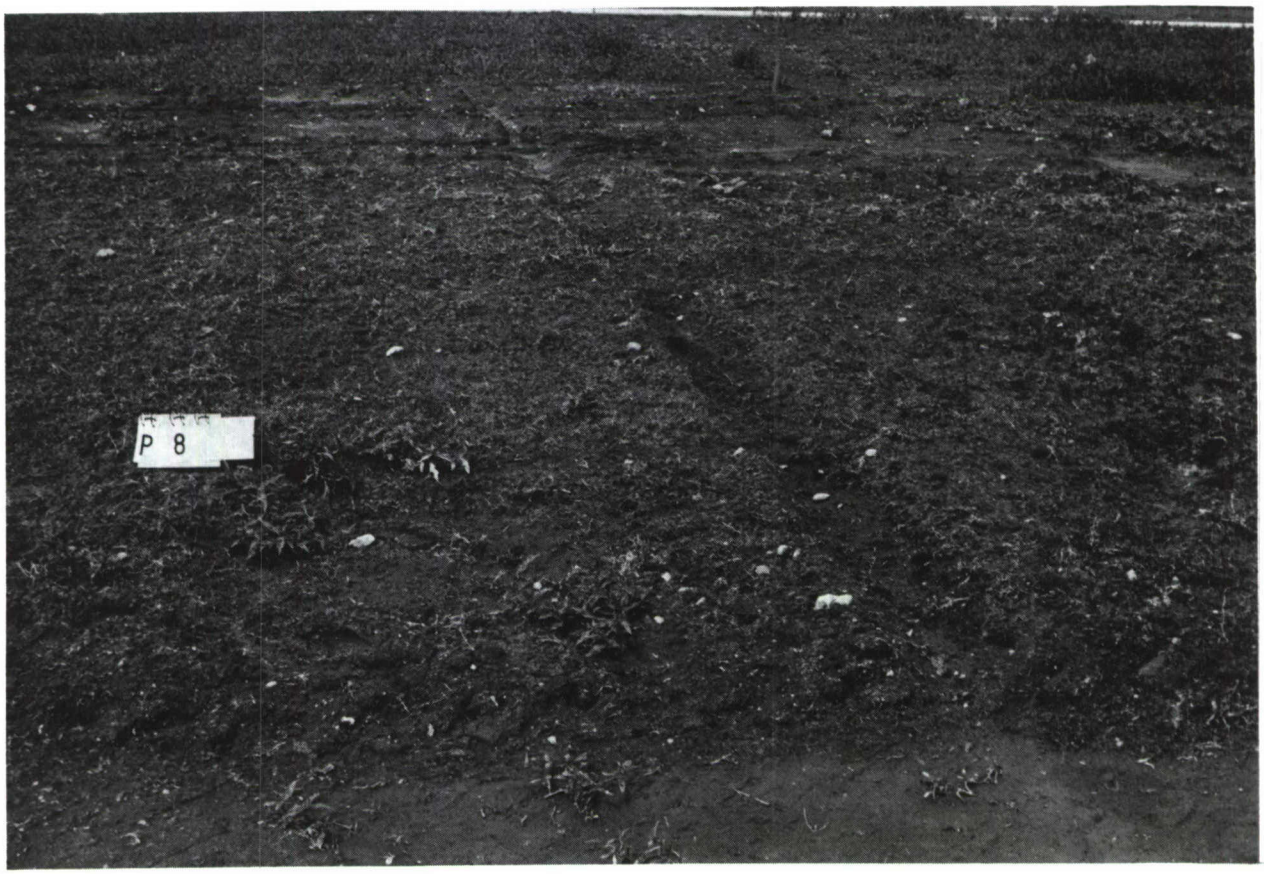

FIGURE 40. Field Test 6 - Bermuda sprigs, 2 days after application.

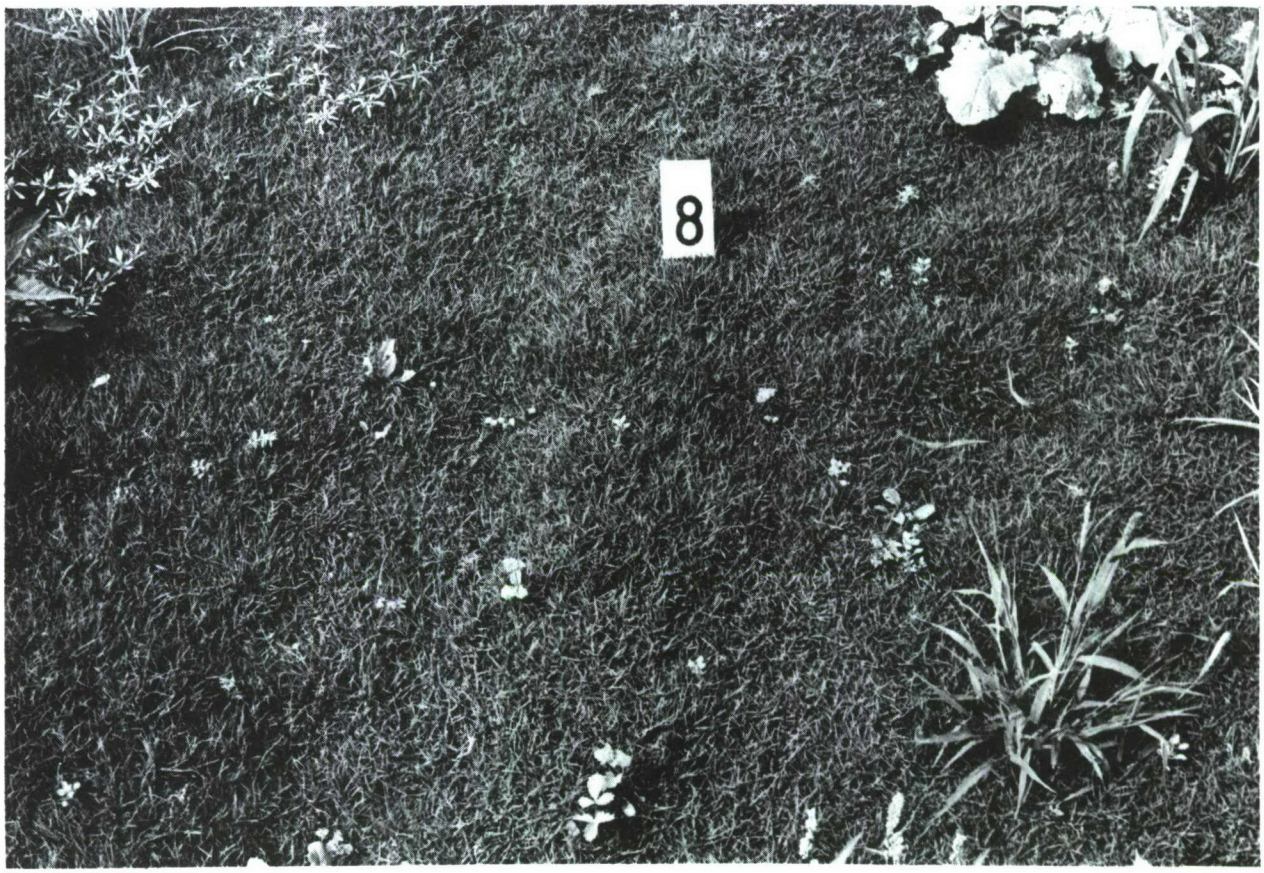

FIGURE 41. Field Test 6 - Bermuda sprigs, close-up, 36 days after application.

Field Test 7

Objective: determine if large-seeded vines can be established by hydroplanting technique.

Date: 6 August 1973

Site: pole shelter at Bldg. 1301

Plots: 6 x 15 ft; single plots; total of 3

Variables: species

Treatment: Hydroplant with Bowie Hydromulcher.
Slurry mixture: 1500 lb/A wood fiber mulch; 500 lb/A of 10-10-10 fertilizer and 120 lb/A of each seed

Species: Lagenaria gourd
Mixed gourds
Ovifera gourd

Post-planting conditions: irrigation applied as required

Results: Good to excellent stands were secured in 30 days but coverage was extremely slow. The test indicates that such vines must be irrigated for adequate growth during periods of high temperature and low humidity. Figure 42 shows the growth of Lagenaria gourds 30 days after planting with the hydromulcher.

Field Test 8

Objective: determine the effects of soil stabilizers and supplemental irrigation on the establishment of a warm-season mixture

Date: 8 August 1973

Site: Area I

Plots: 20 x 30 ft; three replicates of treated plots; two replicates of untreated controls; total of 28 plots

Variables: Curasol AE soil stabilizer at 0, 30 and 60 gal/A
Terratack soil stabilizer at 0, 25 and 50 lb/A
Supplemental irrigation of 1 and 2 inches in split-plot design

Treatments:
1. Untreated control; 1 inch irrigation
2. Untreated control; 2 inch irrigation
3. Curasol AE at 30 gal/A; 1 inch irrigation
4. Curasol AE at 30 gal/A; 2 inch irrigation

FIGURE 42. Field Test 7 - Lagenaria gourds, planted with hydromulcher, 30 days after application.

5. Curasol AE at 60 gal/A; 1 inch irrigation
6. Curasol AE at 60 gal/A; 2 inch irrigation
7. Terratack at 25 lb/A; 1 inch irrigation
8. Terratack at 25 lb/A; 2 inch irrigation
9. Terratack at 50 lb/A; 1 inch irrigation
10. Terratack at 50 lb/A; 2 inch irrigation

All treatments applied by Bowie Hydromulcher with 1500 lb/A of mulch, 500 lb/A of 10-10-10 fertilizer, and 3,000 gal/A of water.

Species: Mixture of sorghum-sudan hybrid (FFR-66), Proso millet and rape.

Post-planting conditions: Supplemental irrigations were made on the day of planting and one day later; subsequent rainfall invalidated the requirement for additional irrigation after this period. Natural rainfall provided an additional 0.5 inch during the first week after planting and 1.75 inches fell within 12 days after planting.

Results: No significant differences were noted in the rate of establishment and subsequent height growth attributable to the soil stabilizer materials. Because of the heavy rains no differences in plant cover or growth due to supplemental irrigation could be isolated. Table 6 presents data on percent stand density and height of the sorghum-sudan hybrid at 30 and 60 days, respectively, with data pooled for the two rates of irrigation. Figure 43 shows the development of vegetation 30 days after hydroplanting.

No significant loss of soil through erosion was noted on the plots receiving soil-stabilizer treatments. Future tests of this type should be conducted on sloping areas to assess soil-erosion capabilities of these materials.

TABLE 6

PERCENT STAND DENSITY AT 30 DAYS AND HEIGHT (CM) AT 60 DAYS OF SORGHUM-SUDAN HYBRID IN FIELD TEST 8. DATA REPRESENT POOLED AVERAGES FOR TREATMENTS RECEIVING 1 AND 2 INCHES OF SUPPLEMENTAL IRRIGATION.

Treatment	% Stand Density	Height (cm)
Control	42.5	152.5
Curasol at 30 gal/A	45.0	146.6
Curasol at 60 gal/A	45.0	153.3
Terratack at 25 lb/A	43.3	148.3
Terratack at 50 lb/A	44.9	150.0

FIGURE 43. Field Test 8 - Rape, sudan, and Proso millet 30 days after application.

Field Test 9

Objective: demonstrate the feasibility of establishment of a warm-season mixture on recently bulldozed area with tree and grass cover.

Date: 17 August 1973

Site: Area I, in tree plantation with dense stand of mixed pasture grasses.

Plot: irregular shape, approximately one-half acre in size

Treatment: Hydroplanted with Bowie Hydromulcher.
Slurry mixture: 1,500 lb/A of wood fiber mulch, 100 lb/A of 10-10-10 fertilizer, 3000 gallons water/A.

Species: Mixture of sorghum-sudan hybrid (FFR-66), foxtail millet and annual ryegrass.

Pre-planting conditions: Entire area bulldozed to remove trees and perennial grass sod; double disced prior to hydroplanting and irrigated the preceding day.

Post-planting conditions: Irrigated following planting and at approximately weekly intervals for one month after planting. Additional fertilizer was applied on 7 September (12 lb/A of 20-20-20 fertilizer).

Results:
Germination was observed in four days and by 18 days the plot was completely covered with vegetation. The sorghum-sudan hybrid and foxtail millet comprised 90% of the stand.

Figures 44 through 46 show the test at the time of planting and at 19 and 24 days following hydromulch application.

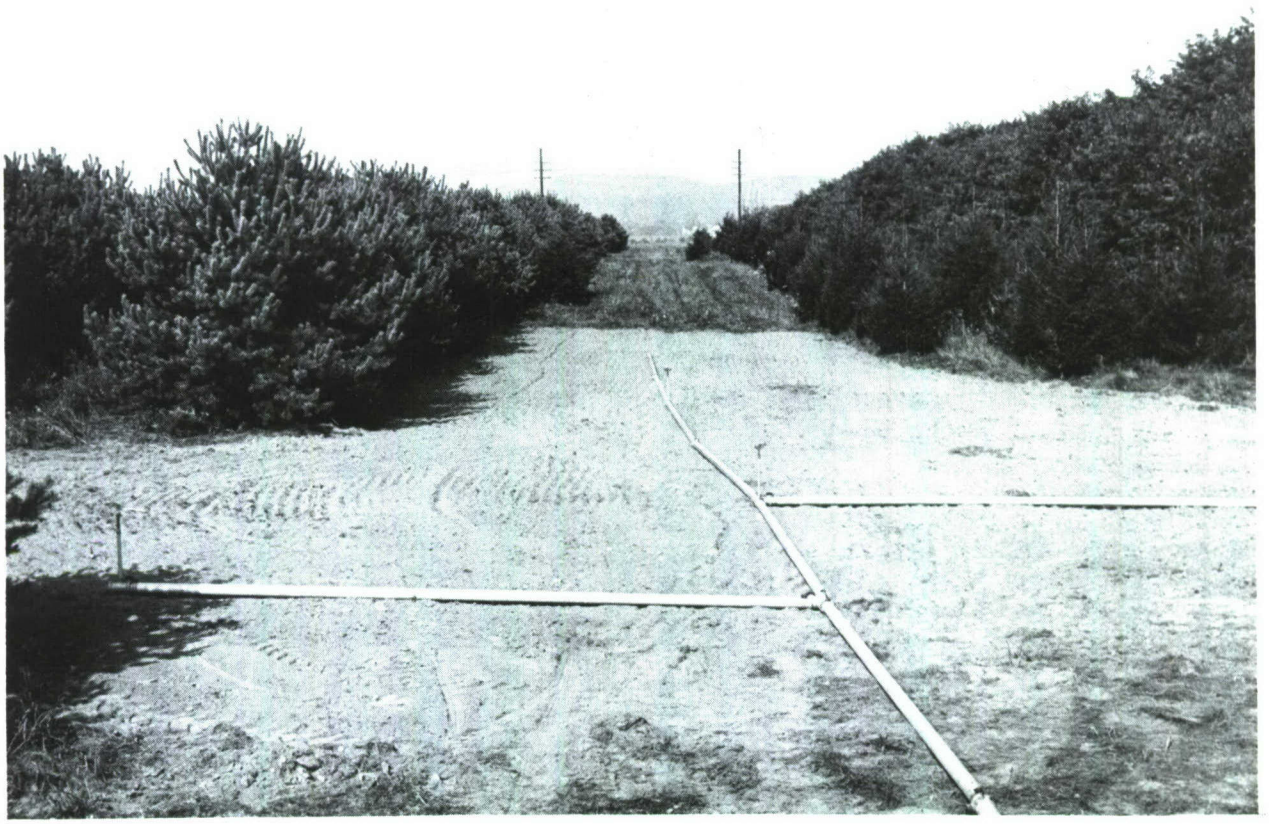

FIGURE 44. Field Test 9 - Plot prepared for planting (Hydromulcher).

FIGURE 45. Field Test 9 - 19 days after application. Sorghum-sudan hybrid, foxtail millet and annual ryegrass.

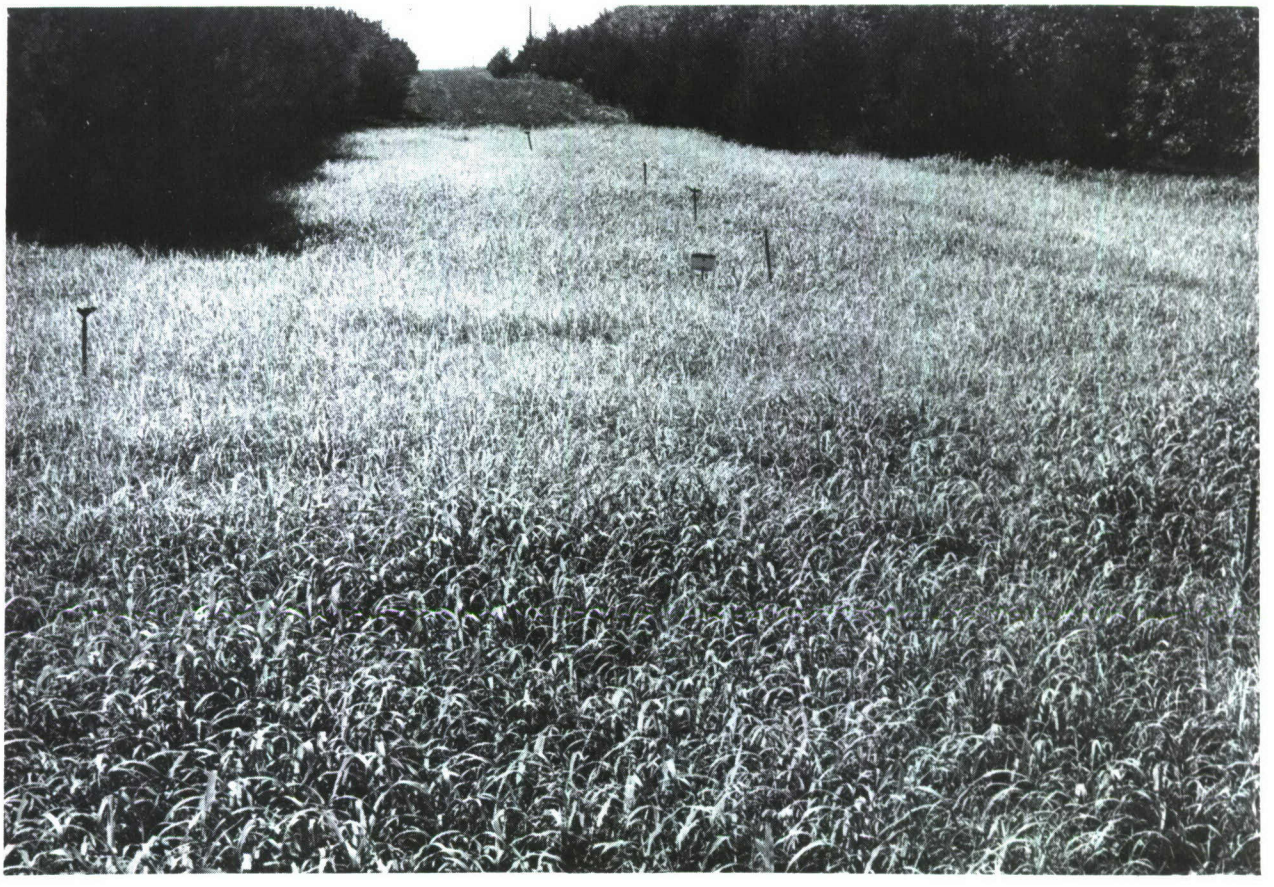

FIGURE 46. Field Test 9 - 24 days after application.

GENERAL DISCUSSION

The general discussion will be related to five specific objectives.

1. Selection of rapid-growing species adaptable to establishment by hydroplanting techniques. - Greenhouse soil tests showed that Ovifera gourd, Lagenaria gourd, cypress-vine, balsam-apple and scarlet runner bean were effective in rapid establishment under ample moisture conditions. Field tests with hydromulching equipment gave less satisfactory results due to unfavorable high temperatures and limited moisture.

Broadleaf plants showing most active growth in greenhouse soil tests were Kobe lespedeza, field peas, field beans, white clover, buckwheat and soybeans. Many of the species tested in this program had never been reported as used in a hydroplanting or hydroseeding system. Large-seeded legumes and some vines were found not desirable because of apparent physical damage of the seed during application. Pre-soaking of seed for several hours may alleviate this type of injury.

Early-summer greenhouse soil tests involving grasses showed sudangrass, weeping lovegrass, bermudagrass (sprigs), Proso millet, redtop, annual ryegrass, and creeping red fescue as most rapid in establishment. Mid-summer greenhouse soil tests conducted under high temperatures gave best results with weeping lovegrass, sorghum-sudan hybrid, Proso millet, and Piper sudangrass. Subsequent field tests during periods of high temperature and low humidity gave the most rapid coverage with sorghum-sudan hybrid, foxtail millet, Proso millet, weeping lovegrass, oats and bermudagrass. Buckwheat, rape, and hairy vetch were the most desirable broadleaf species tested. In all field tests during the warm season, the grasses assumed dominance over the broadleaf components.

In greenhouse tests during the cool season, annual ryegrass was one of the most rapid-establishing species. More extensive tests will be made of cool-season species in the continuation project in 1974 under both greenhouse and field conditions. Cool-season components which were planted in early-summer field tests showed general dormancy during the midsummer period but several species including Kentucky 31 fescue and smooth brome were assuming dominant growth by the end of September 1973.

2. Development of artificial media or substrates for use in hydroplanting equipment.- The most useful artificial media found in the greenhouse tests were methyl cellulose or bacto-agar mixed with wood fiber mulch and an excelsior mat topmulched with wood fiber. Fiberglass mats, rigid urethane foam, and styrafoam materials were generally unsatisfactory. In other tests in which media or substrates were applied to suspended camouflage netting with or without waterproof backing proved to be generally unsatisfactory under the relatively high temperatures.

For most of the artificial media tested, the major limitation was the necessity for frequent watering to sustain plant growth.

3. Determination of useful life-span of vegetative cover establishment by hydroplanting. - Greenhouse studies with artificial substrates showed that methyl cellulose can sustain seedling growth of annual ryegrass and redtop for more than 60 days if topmulched with a wood fiber mulch and watered and fertilized on a regular basis. Other artificial media without a topmulch of wood fiber failed to support growth of test plants for more than 30 days.

Consideration of plant longevity must take into account the distinction in growth habit into annual and perennial, coupled with the temperature requirement as cool-season or warm-season. For plants grown on soil, the principal limitations on longevity are the life cycle of the plant, temperature and the amount of moisture available. Many of the plants used in this program were warm-season annuals (see Appendix A), usually planted in late spring or early summer. Cool-season annuals may be planted in spring or fall; fall-planted annuals such as annual ryegrass will overwinter, flower, set seed and die during the summer. Warm-season perennials are usually planted in late spring or early summer in warm climates but in areas of extreme cold they must be hardy enough to withstand minimal temperatures. For the Frederick area, bahiagrass, bermudagrass, centipede and carpetgrass are all warm-season perennials of marginal hardiness. They make most of their growth in temperatures of 80 to 95 F. Weeping lovegrass is another perennial which will withstand the cold weather of the Frederick area.

Cool-season perennial species can be established in either spring or fall. Moisture and temperature during the time of germination and establishment are critical. These species grow best with daily temperatures between 60 and 75 F but during periods of high temperature and low moisture established plants may go dormant.

In the field tests with hydroseeding equipment warm-season annuals were planted successfully in July, August and September. A cool-season annual or perennial can be planted at the same time to give a flush of growth after temperatures return to about 75 F or lower, as for example in Field Test 9 in which annual ryegrass was added to provide vegetative cover after the warm-season grasses, sorghum-sudan hybrid and foxtail millet die off. With the addition of perennial cool-season grasses, a continuing cover could be established.

Cool-season annuals or perennials will be the most desirable type of vegetation if extremes of high temperatures are not anticipated. Combinations of cool-season and warm-season species can provide a year-round vegetation cover. For field applications, the selection of species will usually be dictated by the growing conditions within the first two weeks after planting coupled with the conditions of the weather in the season to follow.

4. Capability of the plant cover to withstand erosion. - The occurrence of several storms of high intensity during the field test program provided an opportunity to evaluate the effects of wind and water erosion on hydroplanted areas.

In Field Test 1 a storm of gale proportions with winds of up to 50 mph and 1 inch of rainfall in less than 2 hours occurred several days after planting but prior to germination. Severe erosion occurred on Area 2 with freshly-disced subsoil and no establishment was secured. The other test in Area 1 on prior-cultivated level soil gave the appearance of being completely destroyed but both plots produced a complete vegetation cover in 27 days.

Limited tests with a soil-stabilizing agent, Curasol AE in Field Test 4 gave evidence of greater retention of water and less erosion. Plots lacking Curasol showed shorter growth in height and less satisfactory stand coverage. Field Test 8 involving a comparison of Curasol and Terratack in areas subjected to two levels of irrigation failed to show any significant effect of the soil stabilizer additives. The limited tests with supplemental irrigation showed no differences in erosion characteristics or in vegetation cover.

Hydroplanting or hydroseeding appears to reduce the possibilities of soil erosion. The hydromulching process helps to initiate seedling growth by the physical act of pushing seed into previously loosened soil. In cases where the soil is compacted prior to hydromulching, germination is generally poorer than in cultivated or prepared areas.

5. Evaluation of camouflage characteristics of vegetation established by hydroplanting. - Evaluation of seasonal development and camouflage characteristics of vegetation on the field test plots was made by aerial photographic overflights conducted on 19 July, 10 August, and 31 August 1973 by a jet photographic reconnaissance plane of the 363rd Wing, TAC Reconnaissance, Shaw Air Force Base. Panchromatic, Ektachrome and Infrared Ektachrome photographs were made of the field tests at Areas I and II from an altitude of 1500 feet.

General study of the Ektachrome and Infrared Ektachrome imagery showed the progress of vegetation development on the various field test plots and established the general similarity in imagery characteristics of the hydroplanted areas with adjacent areas of established vegetation. Only one field test (No. 9) involved the establishment of vegetation on bare soil immediately adjacent to undisturbed grass and tree vegetation. In this case photographic coverage was made only 14 days after planting so that contrasts in color were still evident between the newly established plot and the adjacent older vegetation which had considerable old mature growth and grass stubble.

Additional information and evaluation of the aerial photographic coverage may be provided by Mr. James S. Slechta of the U. S. Army Imagery Interpretation Center at Fort Holabird.

APPENDIX A

REFERENCE LIST OF GRASSES, BROADLEAF PLANTS AND VINES TESTED WITH INFORMATION ON TEMPERATURE TYPE, GROWTH HABIT, GERMINATION TIME AND TEST PROGRAMS INVOLVED.

Legend: Temperature Type: C, cool-season; W, warm-season
Growth Habit: A, annual; P, perennial
Tests: 1, laboratory; 2, artificial media; 3, peatmoss pot; 4, greenhouse soil; 5, field

Species	Temperature Type	Growth Habit	Germination (days)	Tests Involved
		GRASSES		
bahiagrass *Paspalum notatum* v. Argentine	W	P	21	4,5
bahiagrass *Paspalum notatum* v. Pensacola	W	P	21	4
bermudagrass (seed) *Cynodon dactylon*	W	P	21	3,4,5
bermudagrass (sprigs) *Cynodon dactylon*	W	P	--	5
bermudagrass (sprigs) *Cynodon dactylon* v. U-3	W	P	--	5
bluegrass, Kentucky *Poa pratensis*	C	P	28	4,5
brome, smooth *Bromus inermis*	C	P	14	5
carpetgrass (seed) *Axonopus affinis*	W	P	21	3,4
carpetgrass (sprigs) *Axonopus affinis*	W	P	--	4
centipedegrass *Eremochloa ophiuroides*	W	P	--	4
corn *Zea mays*	W	A	7	4

Species	Temperature Type	Growth Habit	Germination (days)	Tests Involved
fescue, creeping red *Festuca rubra*	C	P	21	2,4,5
fescue, Kentucky 31 *Festuca arundinacea*	C	P	14	2,4,5
lovegrass, weeping *Eragrostis curvula*	W	P	14	4,5
millet, foxtail *Setaria italica*	W	A	10	5
millet, pearl *Pennisetum glaucum*	W	A	7	4
millet, Proso *Panicum miliaceum*	W	A	7	4,5
oats *Avena sativa* v. Clintland	W	A	10	4,5
oats *Avena sativa* v. Clinton	W	A	10	4
orchardgrass *Dactylis glomerata*	C	P	18	5
redtop *Agrostis alba*	C	P	10	2,4,5
rice *Oryza sativa*	W	A	14	4
ryegrass, annual Italian *Lolium multiflorum*	C	A	14	1,2,4,5
ryegrass, perennial *Lolium perenne*	C	P	14	5
sorghum-sudan hybrid *Sorghum vulgare* x *Sorghum sudanense* v. FFR-66	W	A	10	5
sudangrass *Sorghum sudanense* v. Piper	W	A	10	4

Species	Temperature Type	Growth Habit	Germination (days)	Tests Involved
timothy *Phleum pratense*	C	P	10	5
wheat *Triticum vulgare* v. Red Coat	C	A	7	5
BROADLEAF PLANTS				
alfalfa *Medicago sativa* v. Williamsburg	C	P	7	4,5
beans, bush *Phaseolus vulgaris* v. Red Kidney	W	A	8	5
beans, bush *Phaseolus vulgaris* v. Tenderette	W	A	8	5
buckwheat, common *Fagopyrum esculentum*	W	A	6	2,4,5
clover, Alsike *Trifolium hybridum*	C	P	7	5
clover, crimson *Trifolium incarnatum*	C	A	7	4,5
clover, red *Trifolium pratense*	C	P	7	5
clover, white *Trifolium repens*	C	P	10	2,4,5
cowpea *Vigna sinensis* v. Blackeye	W	A	8	4,5
cowpea *Vigna sinensis* v. Ramshorn	W	A	8	4
dichondra *Dichondra repens*	W	P	10	4,5
indigo, hairy *Indigofera hirsuta*	W	A	8	4,5
lespedeza, common *Lespedeza striata* v. Kobe	W	A	14	4,5

Species	Temperature Type	Growth Habit	Germination (days)	Tests Involved
peas, combine *Vigna* spp.	W	A	8	4
rape *Brassica napus*	C	A	7	4,5
sesbania *Sesbania macrocarpa*	W	A	7	4
soybean *Glycine max* v. Clark 63	W	A	8	4,5
sweetclover *Melilotus alba* v. Hubam	C	A	7	5
vetch, hairy *Vicia villosa*	C	A	14	4,5
	VINES			
ajuga, bronce (rooted cuttings) *Ajuga reptans*	W	P	--	4
balloon-vine *Cardiospermum halicacabum*	W	A		1,3
balsam-apple *Momordica balsamina*	W	A	15	1,3,4
bean, Indian *Dolichos biflorus*	W	A	8	1,3
bean, scarlet runner *Phaseolus coccineus* v. multiflorus	W	A	8	1,3,4
bittersweet, American *Celastrus scandens*	W	P		1,2,3
bittersweet, Oriental *Celastrus orbiculata*	W	P		1,2,3
Black-eyed Susan *Thunbergia alata*	W	P	10	1,3,4

Species	Temperature Type	Growth Habit	Germination (days)	Tests Involved
Black-eyed Susan *Thunbergia gibsoni*	W	P	10	1,3,4
canary-bird vine *Tropaeolum peregrinum*	W	A	6	1,3,4
cardinal climber *Quamoclit sloteri*	W	A	6	1,3,4
Carolina jessamine (rooted cuttings) *Gelsemium sempervirens*	W	P	--	4
cats-claw *Doxantha unguis-cati*	W	P		1,2,3
clematis, climbing *Clematis viticella*	W	P	50+	2
clematis, Japanese *Clematis paniculata*	W	P	50+	1,2,3
clematis, mixed *Clematis* spp	W	P	50+	1,2,3
Confederate-Jasmine (rooted cuttings) *Trachelospermum jasminoides*	W	P	--	4
coral-vine *Antigonon leptopus*	W	P	20	1,3,4
cup-and-saucer vine *Cobaea scandens*	W	A	15	1,2,3
cypress-vine *Quamoclit pennata*	W	A	5	1,3,4
Flag-of-Spain *Quamoclit lobata*	W	P	20	1,3,4
gourd, Lagenaria *Lagenaria* spp.	W	A	8	1,3,4,5
gourd, mixed *Cucurbita* spp.	W	A	8	1,3,4,5

Species	Temperature Type	Growth Habit	Germination (days)	Tests Involved
gourd, Ovifera *Cucurbita* spp.	W	A	8	1,3,4,5
granodilla, purple *Passiflora edulis*	W	A	30	1,2,3
hop, Japanese *Humulus Japonica*	W	A	6	1,2,3
hydrangea, climbing *Hydrangea petiolaris*	C	P		1,2,3
ice-plant *Cryophytum crystallinum*	W	P	5	1,3,4
jasmine, yellow *Gelsemium sempervirens*	W	P	30	1,2,3
kudzu *Pueraria thunbergiana*	W	P	15	1,2,3
madeira-vine (tubers) *Boussingaultia baselloides*	W	P	--	1,4
marble-vine *Bryonopsis laciniosa*	W	A	8	1,2,3,4
moonflower *Calonyction aculeatum*	W	A	11	1,3,4
morningglory *Ipomoea purpurea*	W	A	5	1
morningglory *Ipomoea purpurea* v. Crimson rambler	W	A	5	1,4
morningglory *Ipomoea purpurea* v. Darling	W	A	5	1,3,4
morningglory *Ipomoea purpurea* v. Heavenly Blue	W	A	5	1,4
morningglory *Ipomoea purpurea* v. Scarlet O'Hara	W	A	5	1,4

Species	Temperature Type	Growth Habit	Germination (days)	Tests Involved
passion-flower				
Passiflora spp	W	A	30	1,3
Virginia creeper				
Parthenocissus quinquerfolia	W	P	14	1,2,3,4
wisteria, blue				
Wisteria spp	W	P	30+	1,3,4

APPENDIX B

MULCHES, MEDIA AND SUBSTRATE MATERIALS AND SOIL STABILIZERS USED IN TEST PROGRAM

Item	Source
Mulches	
Conwed Hydromulch	Conwed Company
PFM (Pulp Fiber Mulch)	Weyerhauser Company
Silva Fiber	Weyerhauser Company
Superior Hydromulch	Wolbert & Masters Company
Media and Substrate Materials	
Methyl cellulose, USP 4000 centopoise	Fisher Scientific Company
Dacagin, polysaccharide gum, granular	Diamond Shamrock Company
Bacto-agar	Difco
Ultracheck Landscape Mat 1/4 inch, 1/2 inch and 1 inch	CSG Insulation Corp.
Tufcote Plastic Foam 1/2 inch and 3/4 inch	Specialty Converter Co.
Styrafoam, laminar sheets 1/2 inch and 1 inch	
Polyurethane foam, 1/4 inch sheet	Monsanto Company
Scott Coustex, polyurethane foam 1/2 inch sheet	Stephenson & Lawyer, Inc.
Scott Pyrell, polyurethane foam 1/2 inch sheet	Stephenson & Lawyer, Inc.
Acquell, polyurethane foam 1/2 inch sheet	Bernel Foam Products, Inc.
Scott Industrial Foam 1/2 inch sheet, green	Formade Industries
Vermiculite, attic grade, Zonolite	W. R. Grace, Inc.
KYS Mix	Keyes Fibre Co.
Jiffy-Seven Peat Pellets	Jiffy Products Ltd., Norway
Soil Retention Mat, excelsior mat	American Excelsior Company
Gehring Style Net 3178	Gehring Textiles
Cotton nap with rubberized backing nos. 2-2796, 9-3344, 3-0325	Aldan Rubber Company
Dacron fiber bonded with Mylar, light and heavyweight polyester	E. I. DuPont de Nemours & Co.
Soil Stabilizers	
Gelgard M, thickening agent	Dow Chemical Company
Polyacrylamide X-1029	Dow Chemical Company
Curasol AE	Wolbert & Masters Company
Terratack	Grass Growers, Inc.

APPENDIX C

HYDROPLANTING EQUIPMENT: CHARACTERISTICS AND SOURCES

Hydroplanters, hydroseeders, or hydromulchers are machines used to spray a slurry of water, wood cellulose fiber or other mulch, seed or propagating material, fertilizer, and other water-soluble materials for reseeding highway embankments, lawns and other bare soil areas. The equipment consists of a tank in which the slurry is mixed by mechanical and/or hydraulic agitation with a high-pressure pump for dissemination through a movable gun or an attached hose. Two types of pumps are available: centrifugal and rotary gear. The normal slurry mixtures containing seed can be handled with either a centrifugal or gear pump; grass sprigs and other vegetative material require the use of gear-pump equipment to avoid breakage and damage of the plant material. A high-volume water system is required to fill the machines, either from a fire hydrant or by use of an auxiliary pump to pick up water from ponds, lakes, or other sources of water.

Manufacturers of Hydroplanting Equipment:

Bowie Industries, Inc.
1004 E Wise P. O. Box 931
Bowie, Texas 76230

Reinco
P. O. Box 584
Plainfield, New Jersey 07060

Spray Baby, Inc.
751 North Edmonds Drive
Carson City, Nevada 89701

Toro Eco/Systems Division
8111 Lyndale Avenue South
Minneapolis, Minnesota 55420

Finn Equipment Company
2525 Duck Creek Road
Cincinnati, Ohio 45208

Quality Development Company
Hydro-Turf
P. O. Box 3
Elk Grove Village, Illinois 60007

The following lists summarize the working capacities, type of agitation and pumps available in equipment from the six companies.

Manufacturer	Working Capacity (Gallons)									
	150	250	350	450	500	800	1000	1500	2500	3000
Spray Baby	X									
Reinco		X			X	X	X	X		
Toro					X		X	X		X
Finn						X	X	X		
Bowie			X		X	X	X	X	X	X
Hydro-Turf				X			X			

Manufacturer	Pumps		Agitators		
	Centrifugal	Rotary Gear	Mechanical	Hydraulic	Combination
Spray Baby	X			X	
Reinco	X			X	
Toro	X		X		
Finn	X				X
Bowie	X	X	X		
Hydro-Turf	X				X

Most compaies have units which can be mounted on trailers in capacities up to about 1,000 gallons. Larger units are skid-mounted for placement on flat-bed trucks. Costs range from $1,600 to about $11,000 depending on size and nature of the equipment.

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Aberdeen Proving Ground, MD 21010